Baseline Survey of Alternative In-Line Inspection Vehicles

DOT Agreement No. DTRS56-02-T-0004

SwRI Project 14.06170

Status Review Meeting
October 7, 2003
Southwest Research Institute
San Antonio, TX

Why Pipeline Inspection?

Project Description

- Relates to in-line inspection (ILI) of piggable and unpiggable pipelines
- Contract signed 1 October 2002
- Project term 9 months (extended to 12 mo.)
- Pipeline Research Council, International is co-funder.
- Total project cost is $ 80,000.

Project Goals

- Document scope of problem of unpiggable pipelines
- Document state of the art in ILI capabilities
- Determine tool capability in other applications
- Document conceptual designs including tethered and autonomous robotic vehicles
- Produce comprehensive report of findings

Unpiggable Pipelines

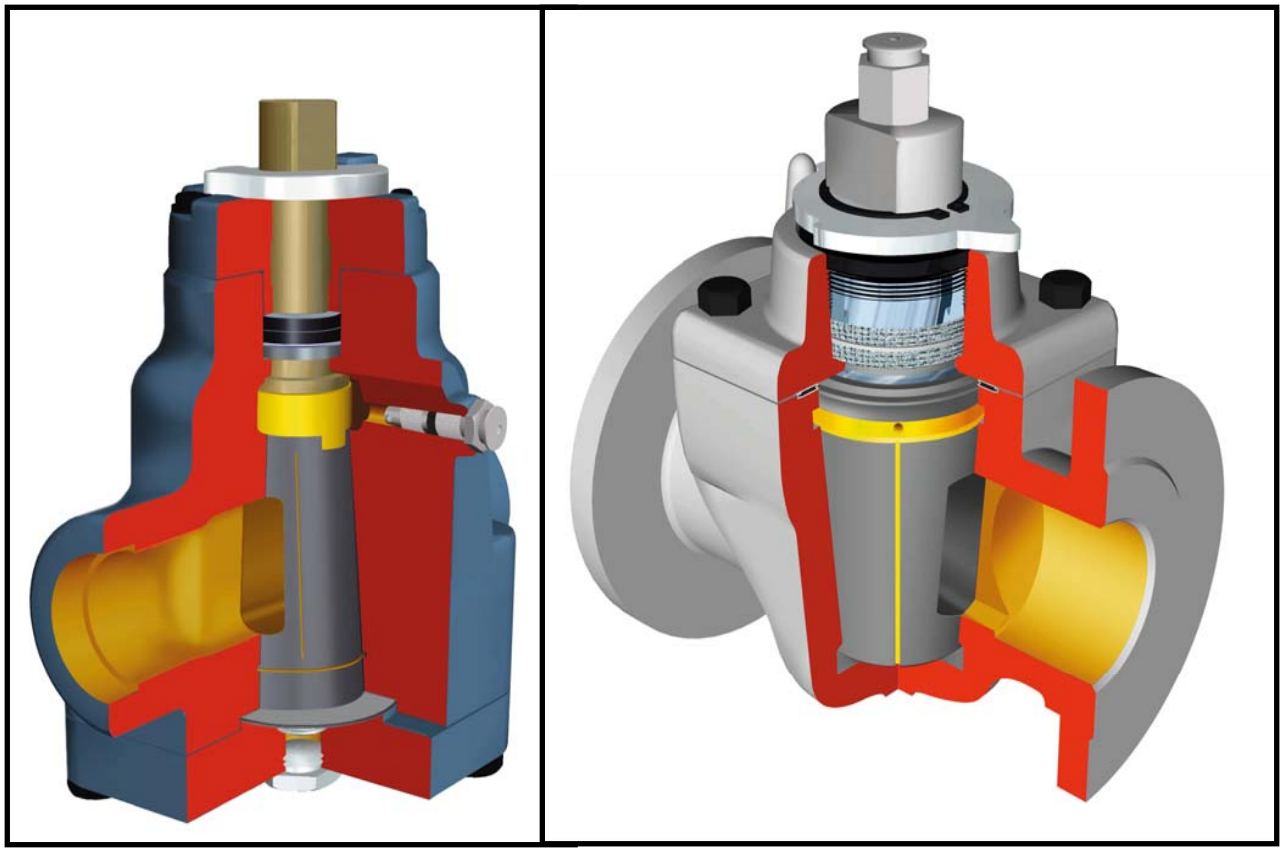
- Restrictive pipe diameters (telescoped lines)
- Restrictive valves (undersized, non-full-opening, plug valves)
- Restrictive bends (Short radius, mitered, heavy wall, back-to-back)
- Low pressure lines
- Low flow-rate lines
- Lack of access (no traps installed)

Bend with Smaller Valve

Tee Branch Connection

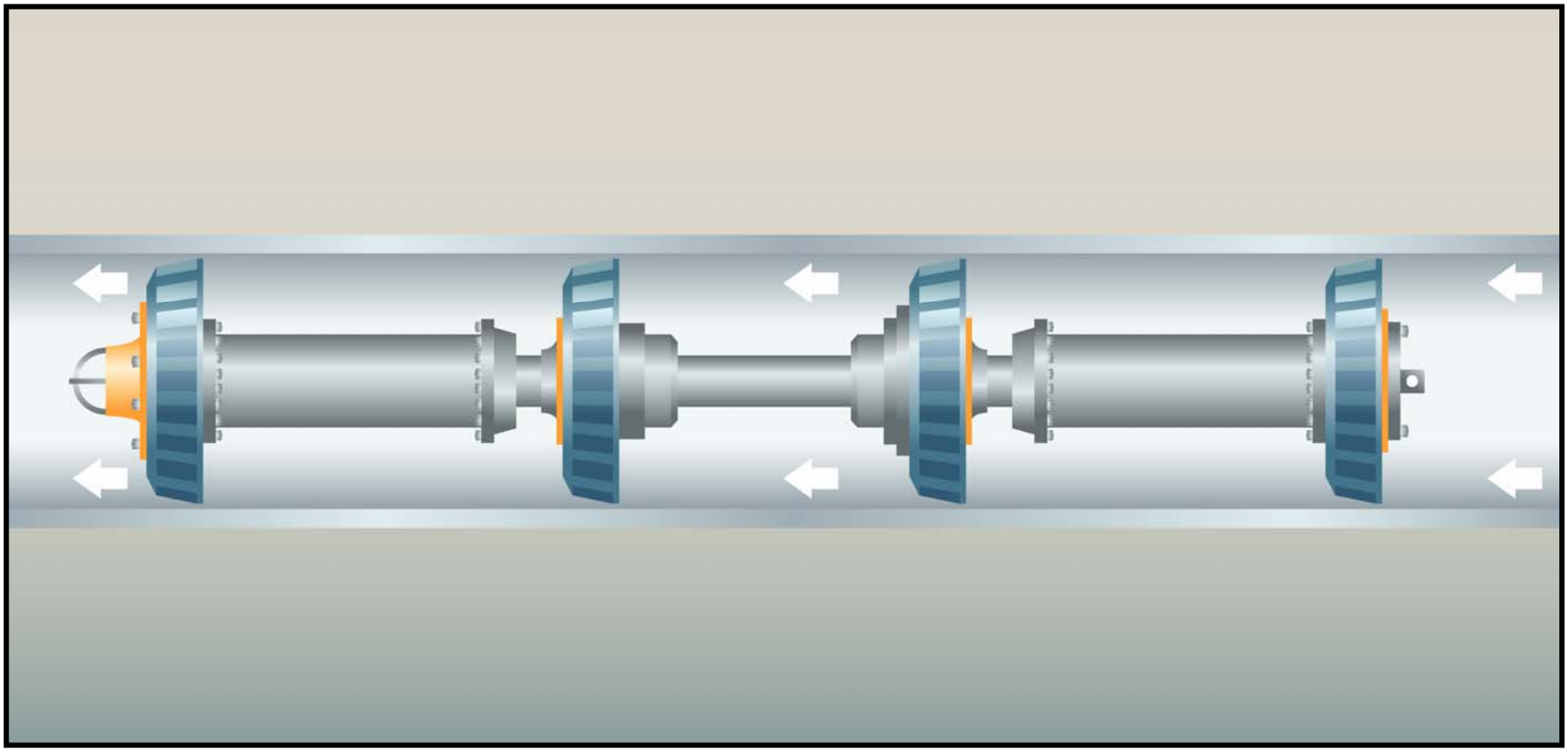
Reduced Tee Branch

Plug Valve Construction

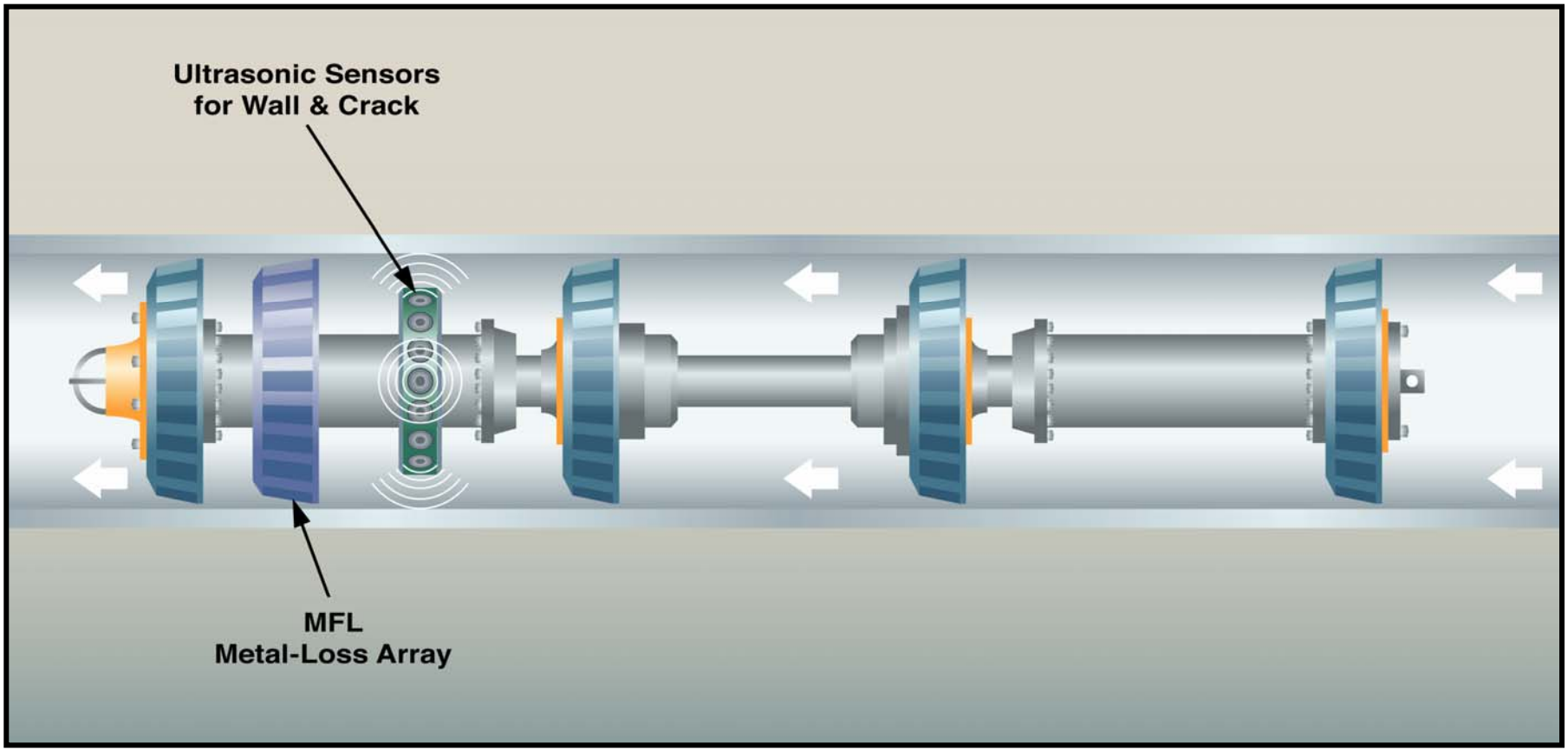


View Looking into Plug Valve

Measurement / Sensors for In-Line Inspection



Measurement / Sensors for In-Line Inspection



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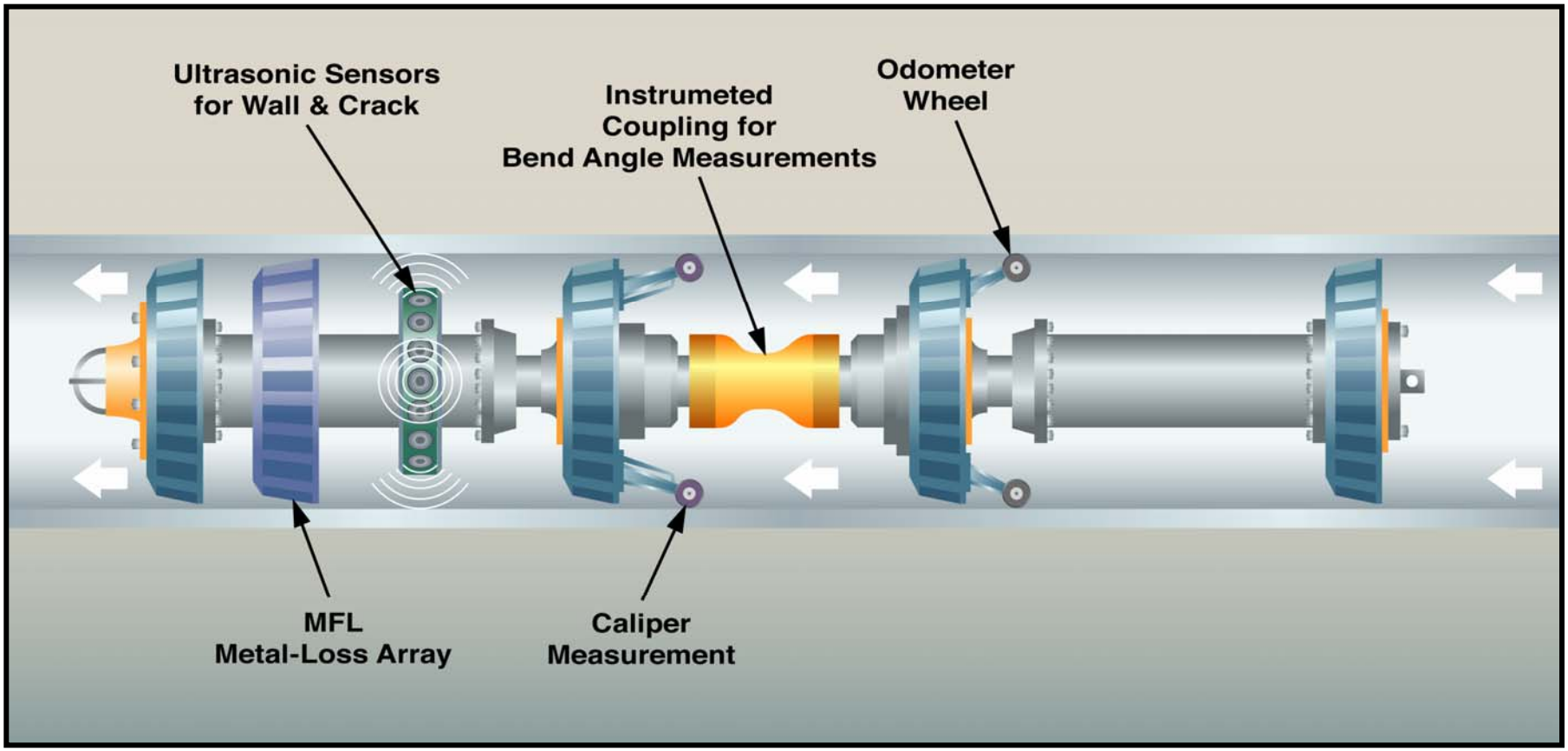

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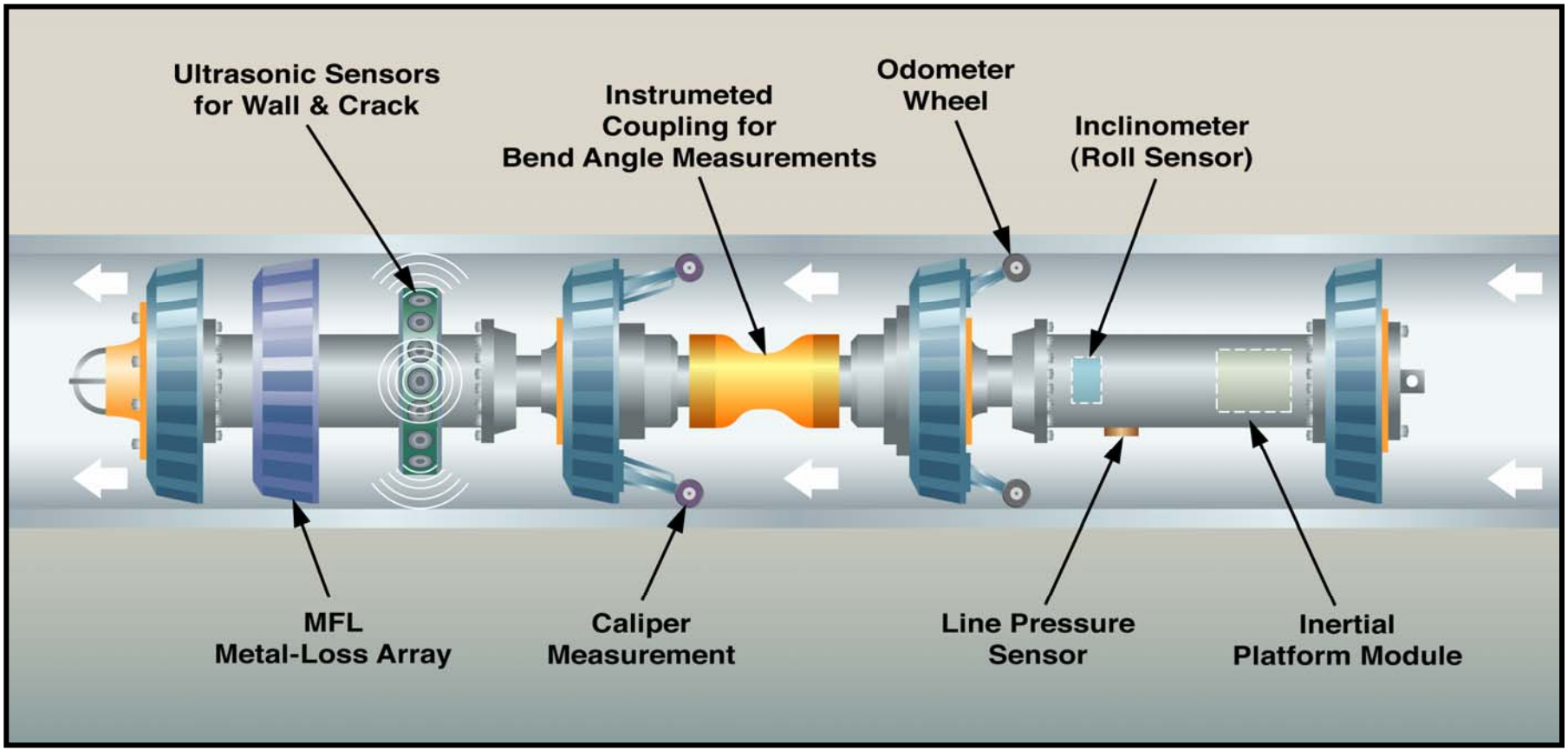
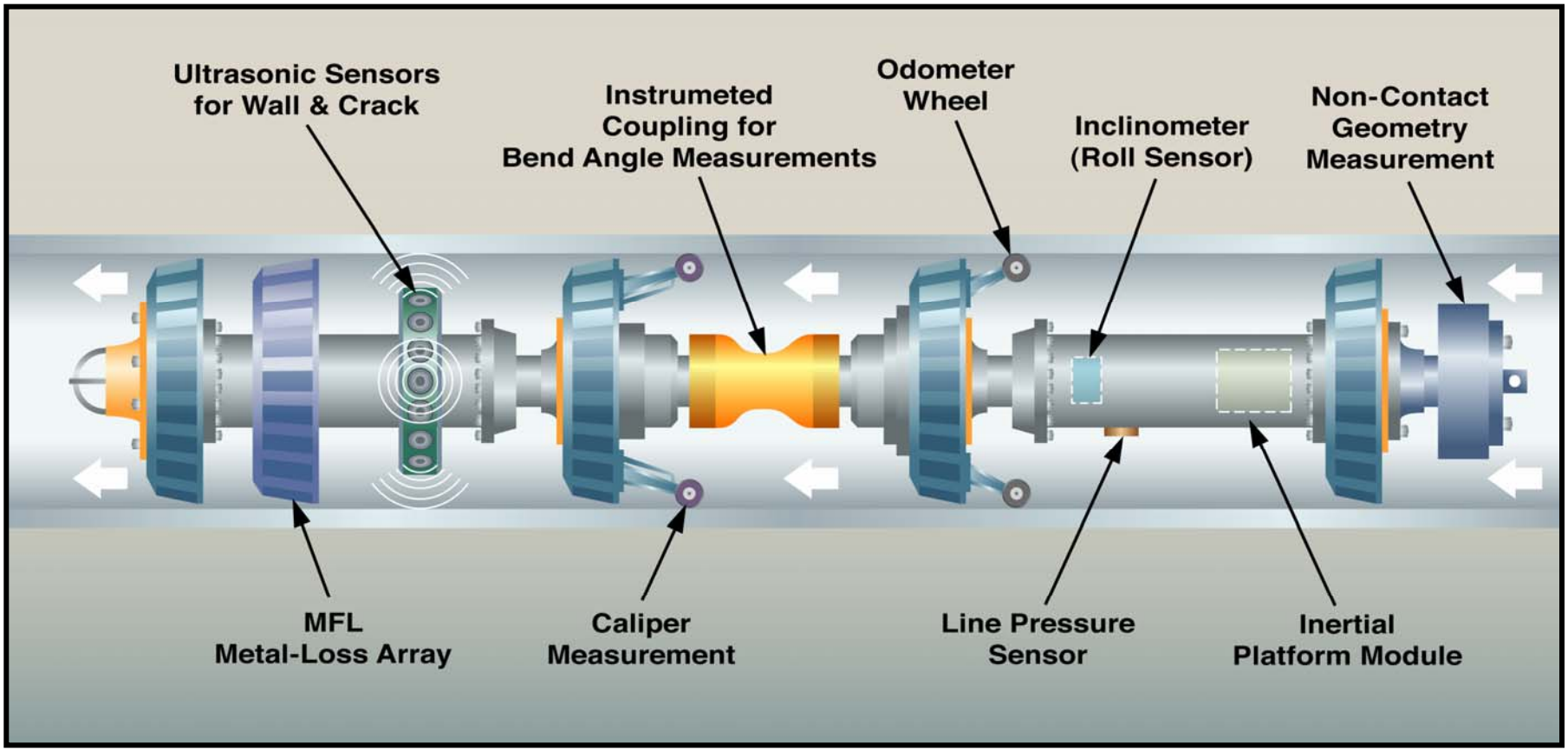
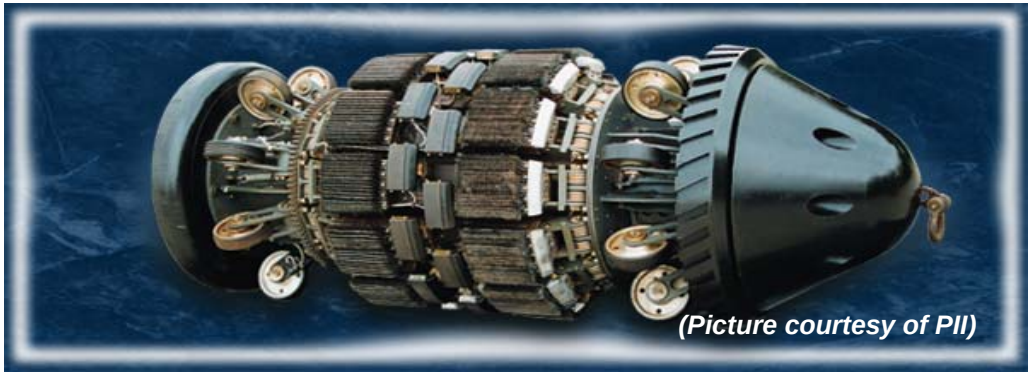
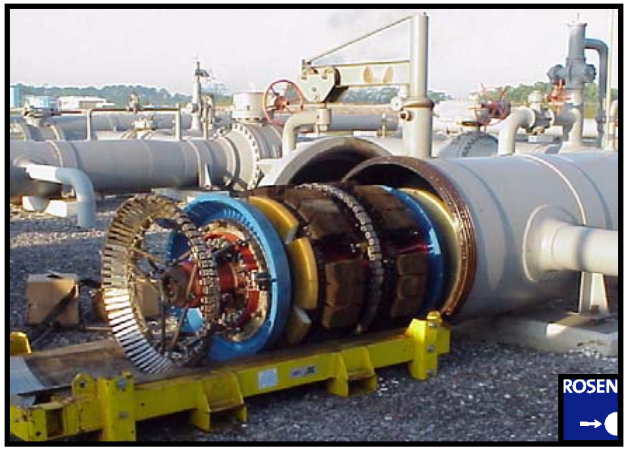


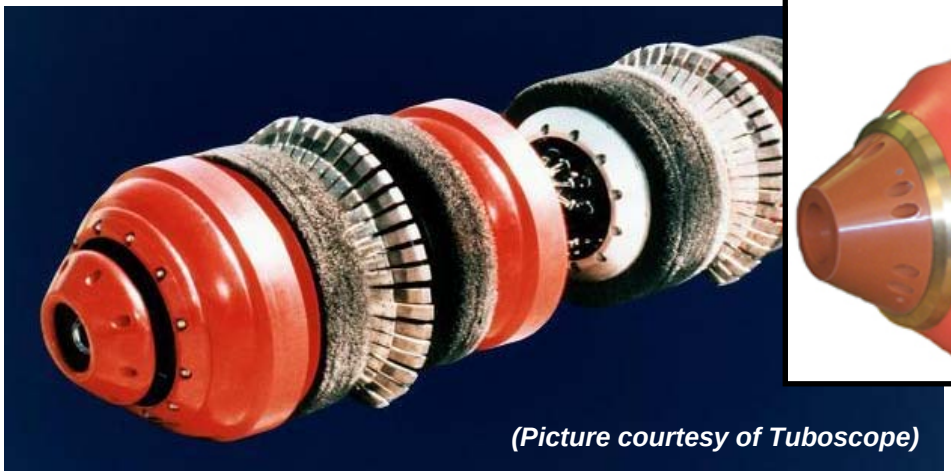
Measurement / Sensors for In-Line Inspection

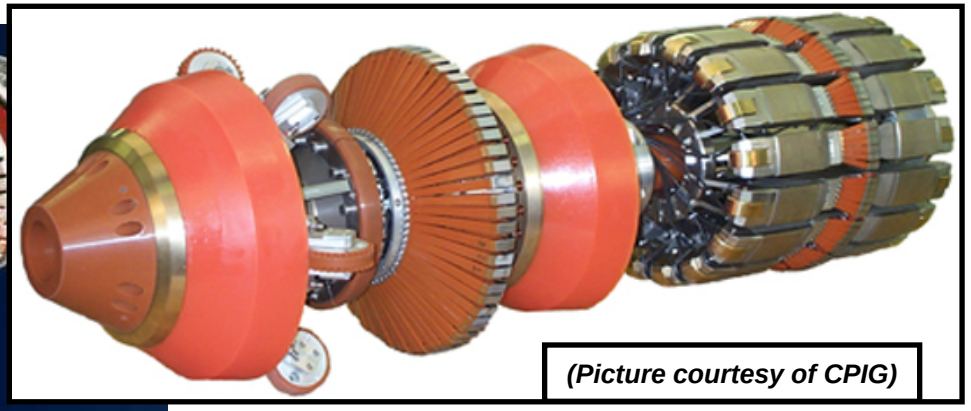


MFL Smart Pigs

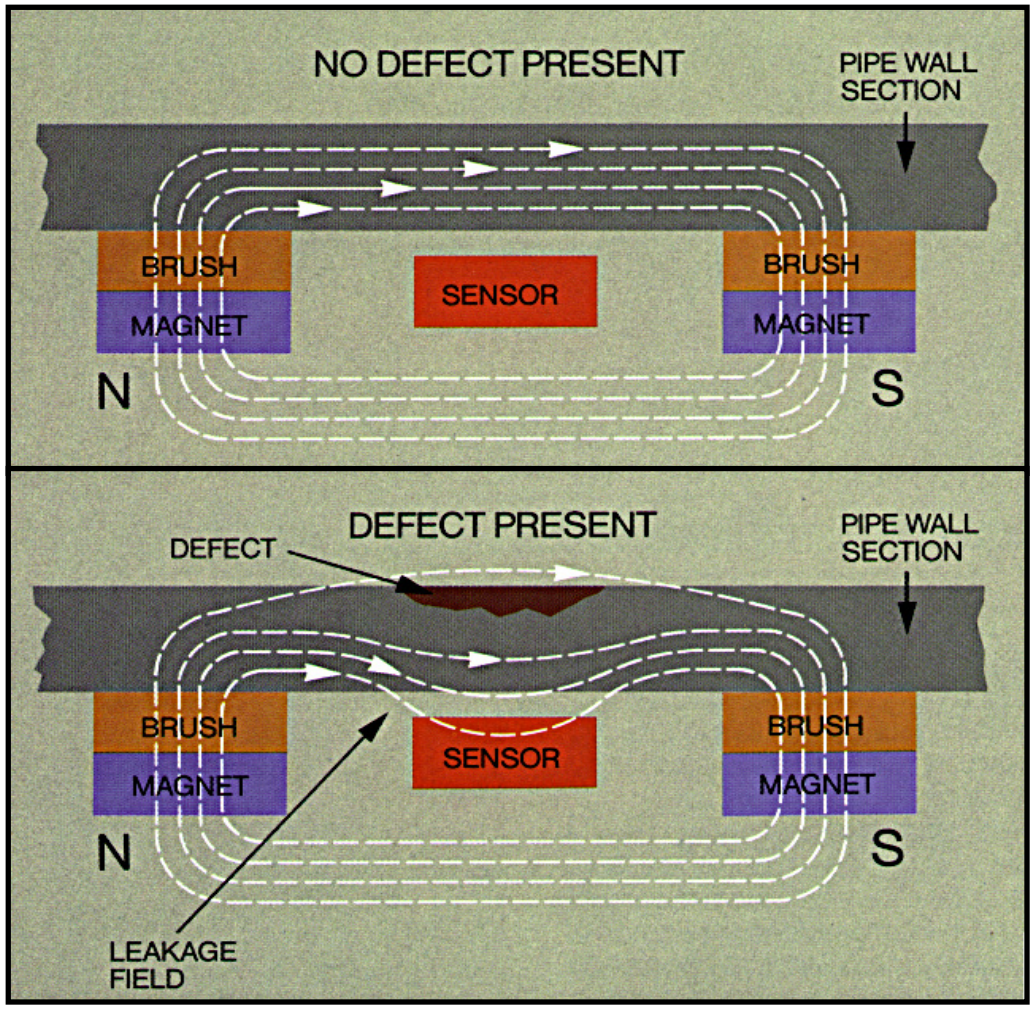




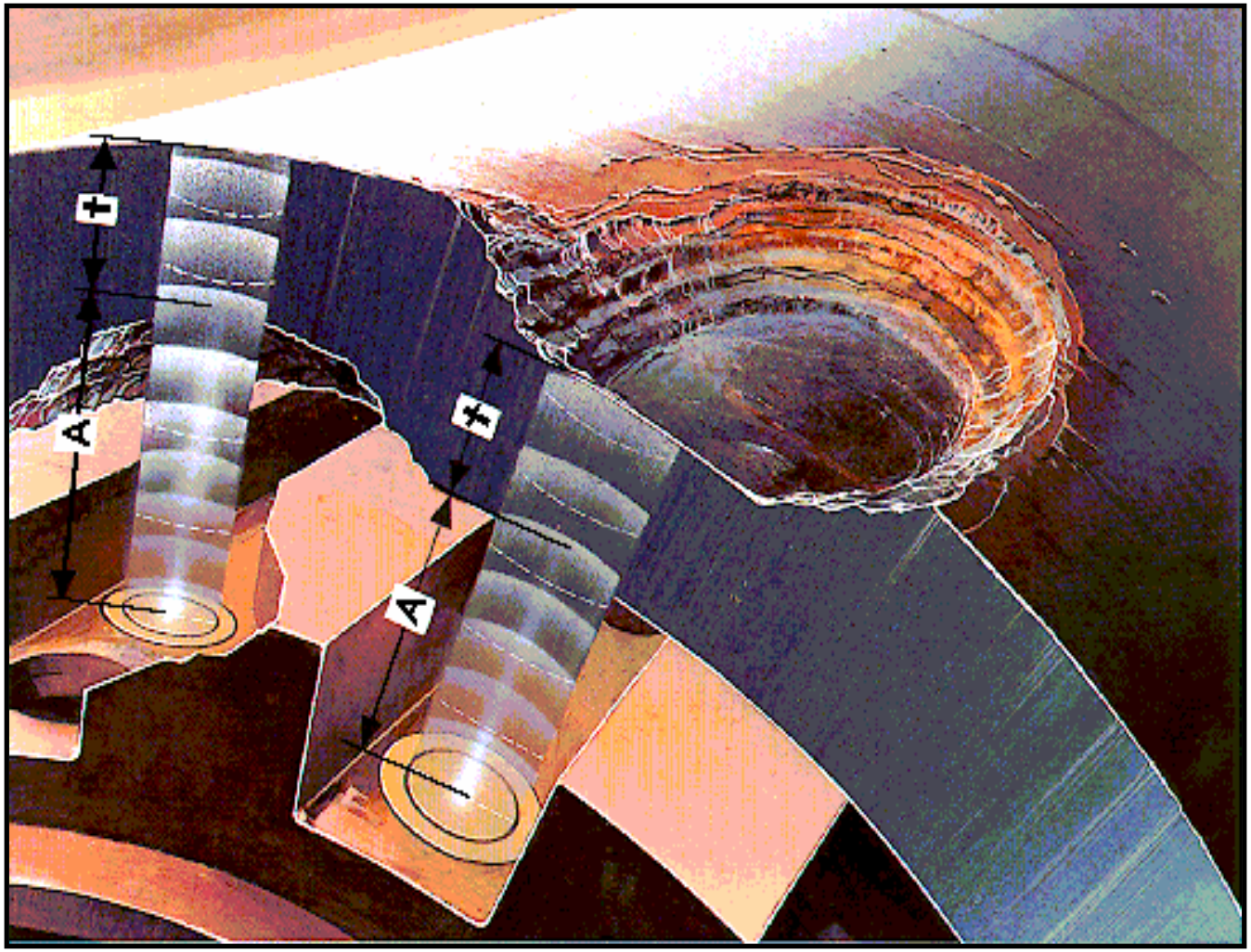




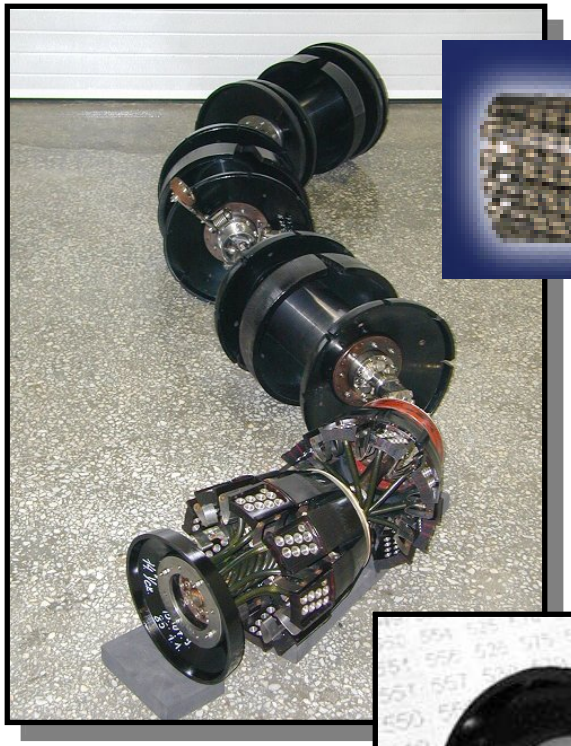
MFL Operating Principle

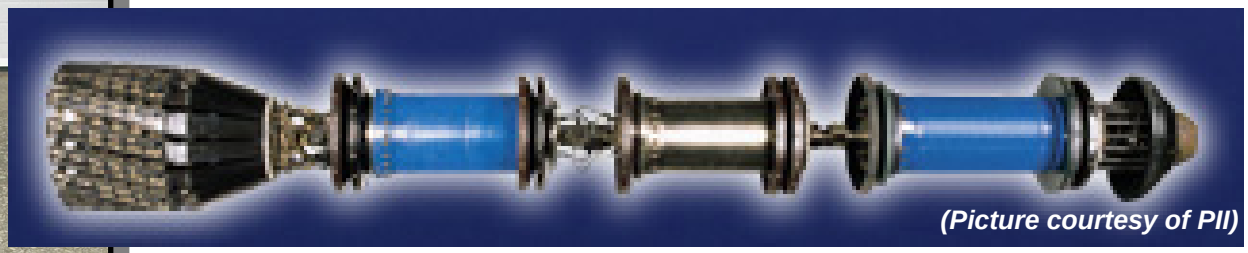


UT Operating Principle

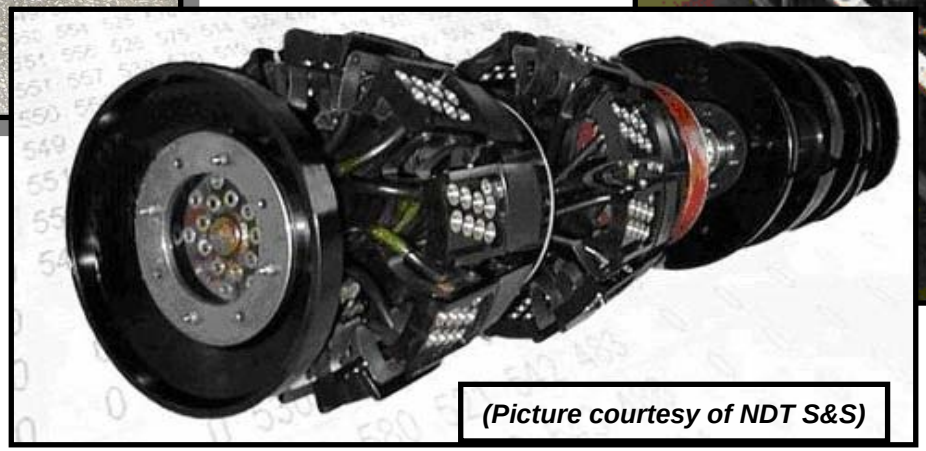


Ultrasonic Smart Pigs





(Picture courtesy of PII)



(Picture courtesy of NDT S&S)

ILI Providers

- BJ Process and Pipeline Services
- Baker Petrolite Corporation
- A. Hak Industrial Services
- NDT Systems and Services
- 3P Services GmbH
- PII Pipeline Solutions (GE Power Systems)
- Rosen Inspection
- Tuboscope Varco

Pig Matrix Parameters

Pipe Size

Number of Modules

Minimum Op. Pressure

Max Wall Thickness

Minbore Continuous

Pig Length

Maximum Unbarred Branch Diameter

NDE Technique

Bend Radius

Max Op. Pressure

Tween Distance

Minbore Delta

Alternative Applications

- Viewing devices (TV crawlers)
- Internal piping repair systems (tethered)
- Sewer inspections, repairs
- Water main inspection (Remote Field EC)
- General robotic devices (surveillance, hazardous environment, mine detection/disposal)

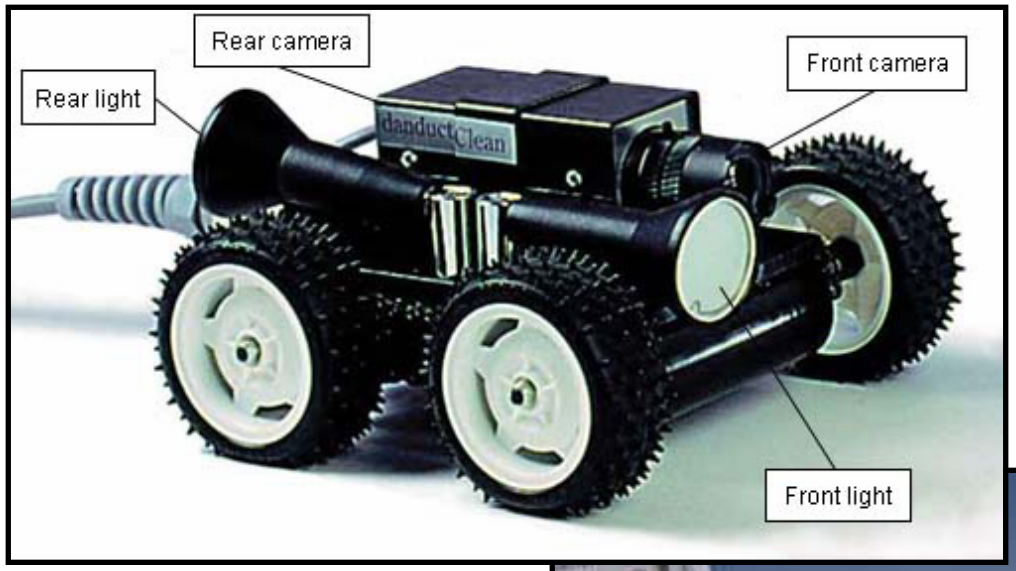
Alternative Concepts

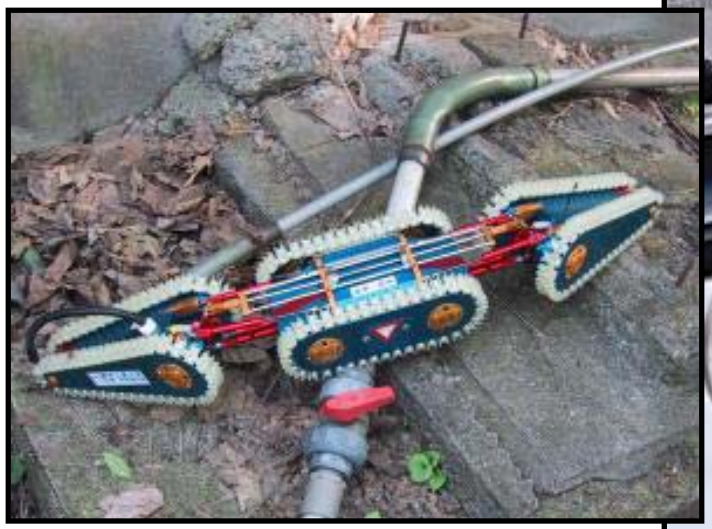
- Caterpillar-track robot
- Articulated linear segment crawler (NYGAS Explorer)
- “Bicycle chain” configurable device (Sandia)
- Inch-worm drive – Push-pull (CTS)
- Robotic snakes

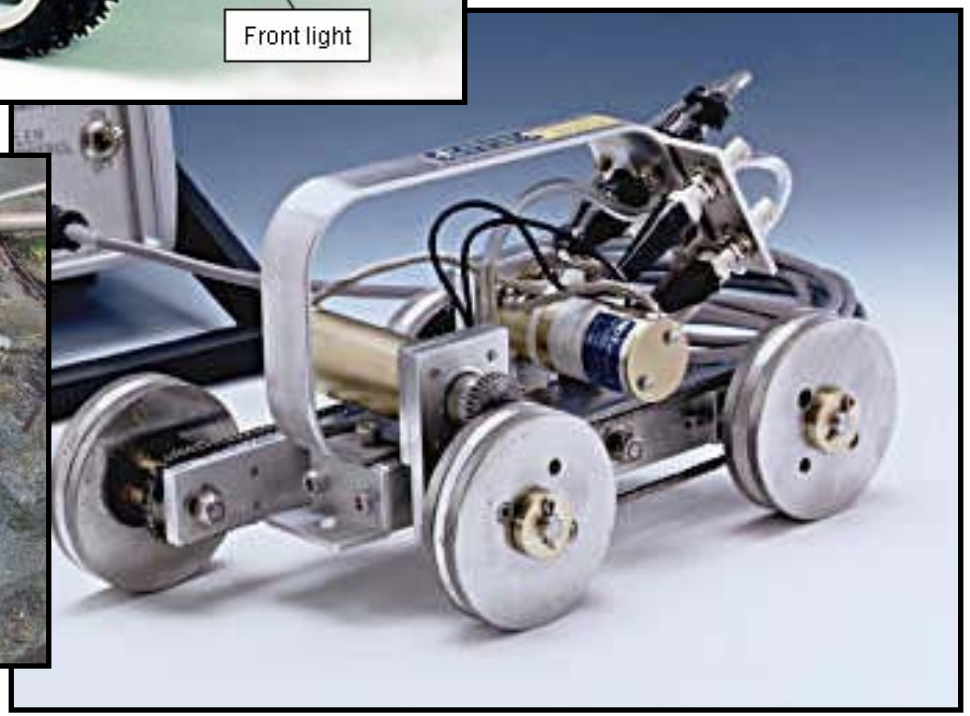
SRI International Pipeline Robot

Pipeline Robot We designed and developed the Magnetically Attached General Purpose Inspection Engine (MAGPIE) to inspect small (15 cm) natural-gas pipes for corrosion and leakage. The robot's magnetic wheels enable it to travel on the ceiling and sides of pipes, and to navigate obstacles such as T-joints, vertical climbs, and sleeve joints. A demonstration robot, with on-board battery power, has been successfully tested; it sends control signals and pipeline video images through a fiber-optic cable.

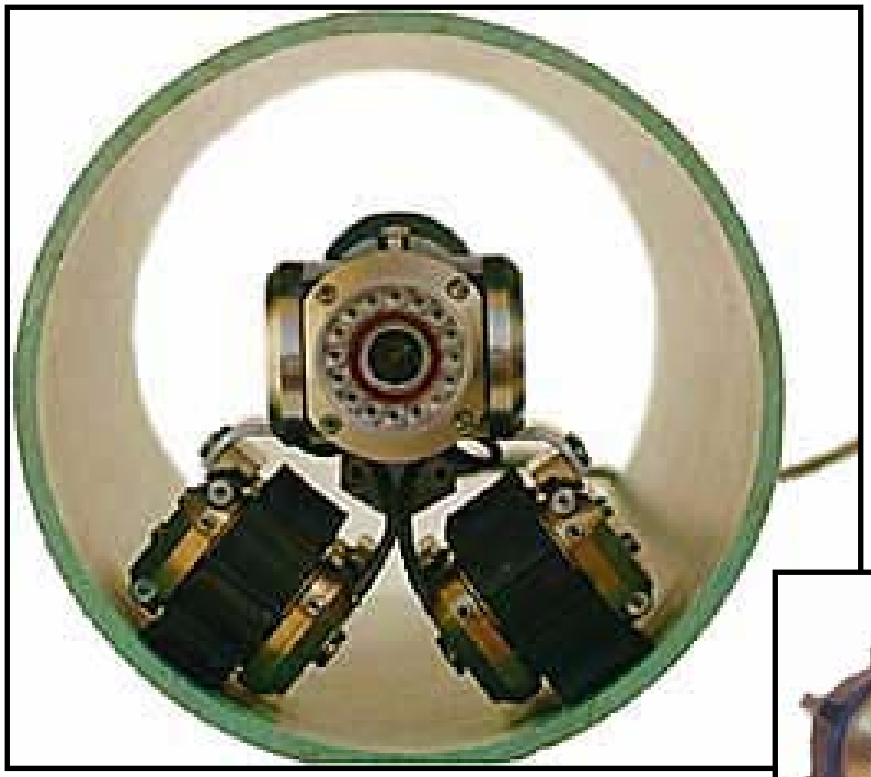
Wheeled/Tracked Crawlers

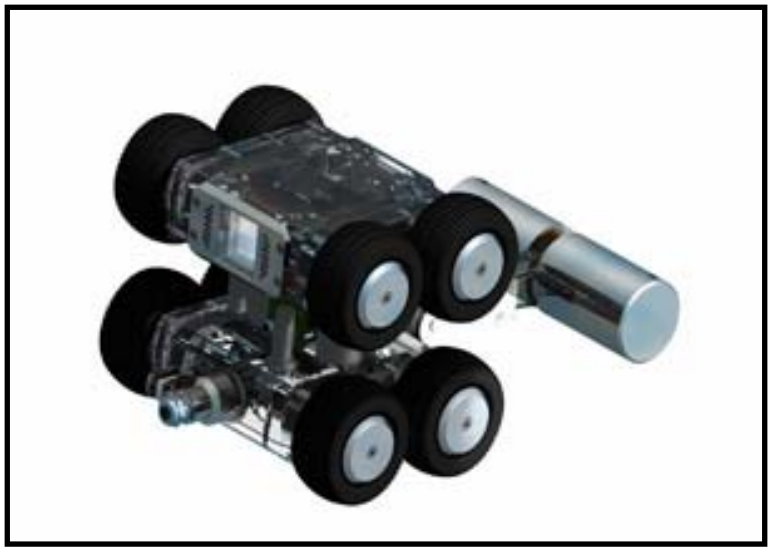




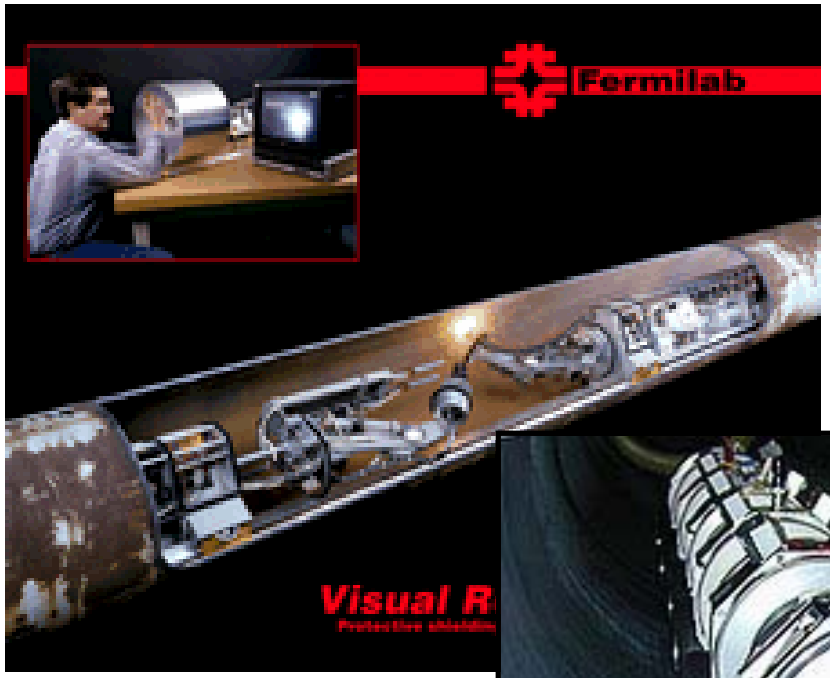


Wheeled Robots in Piping





Devices from other Applications

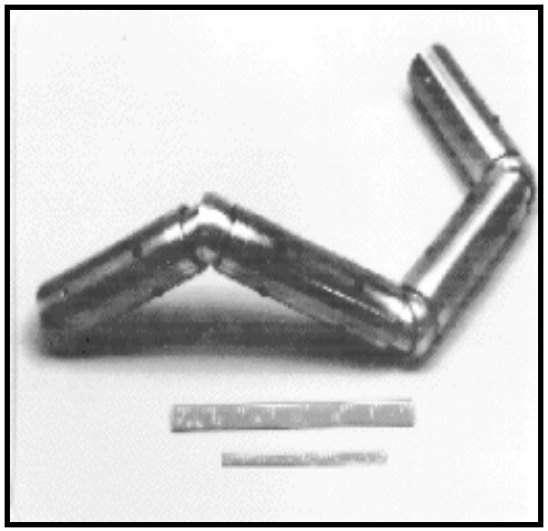


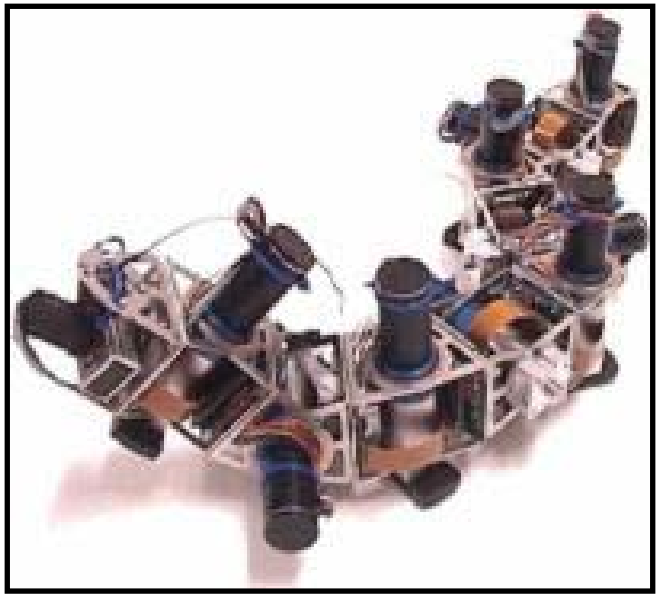
Robotic Welding

Sealant Application

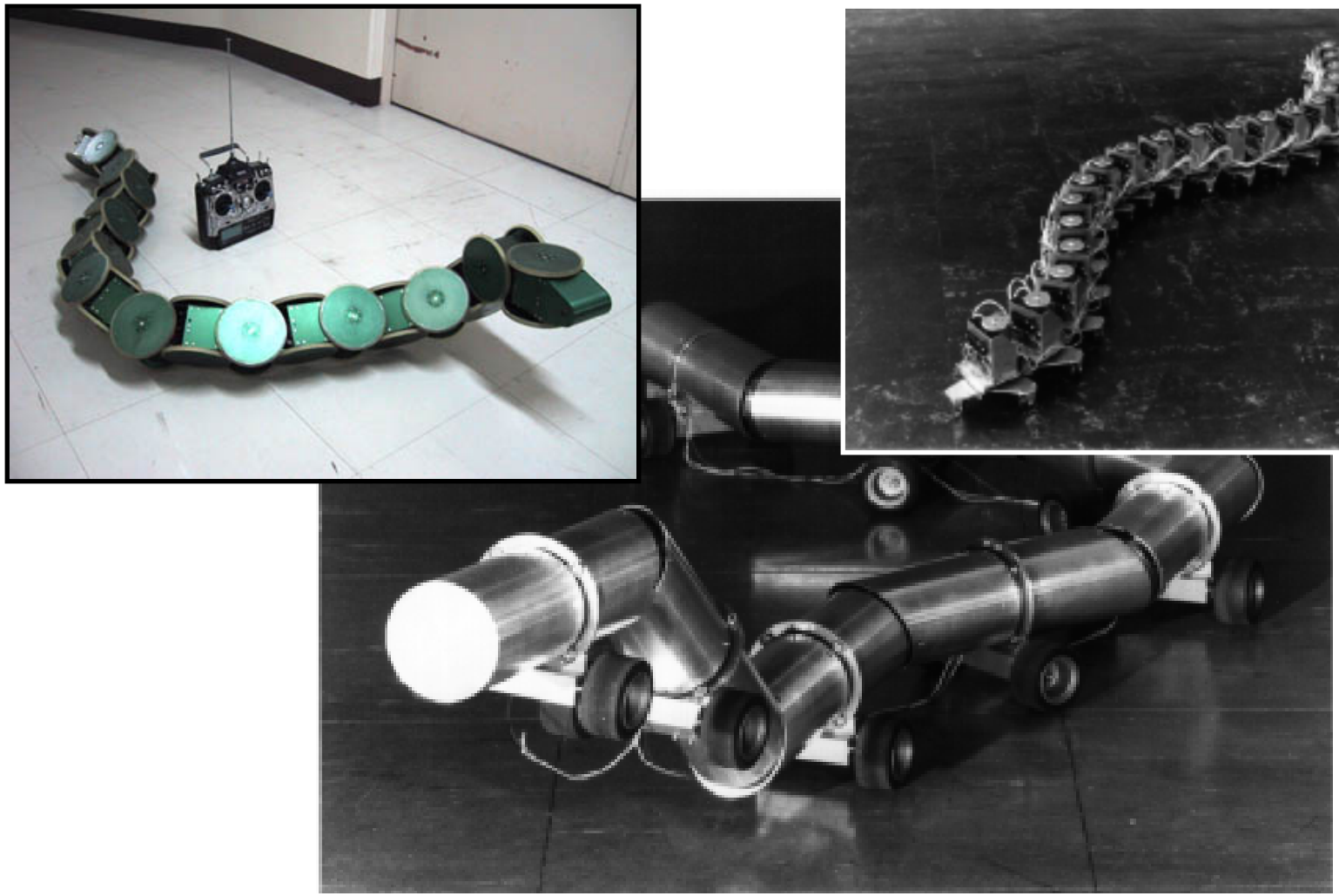
Makro

Snake Robots



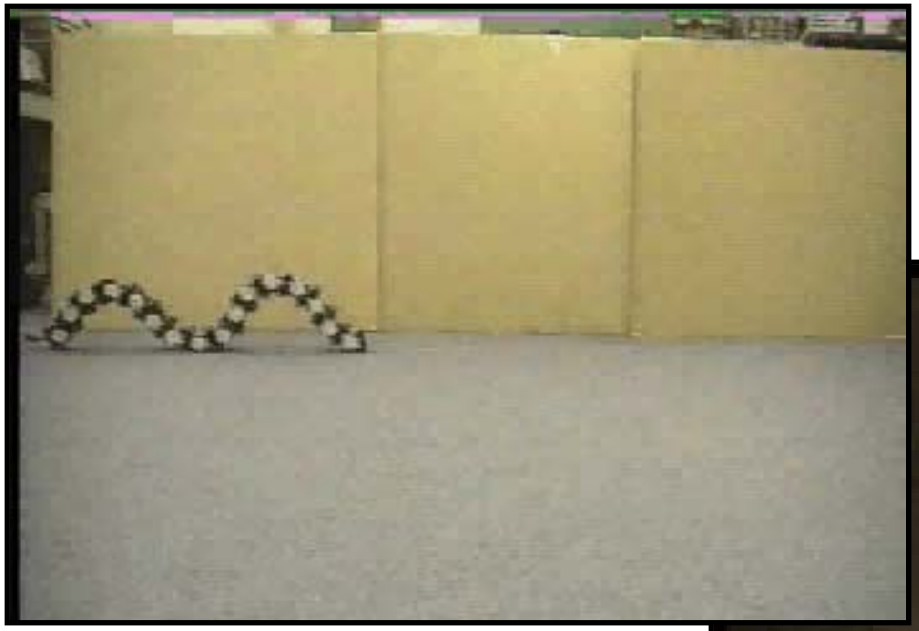


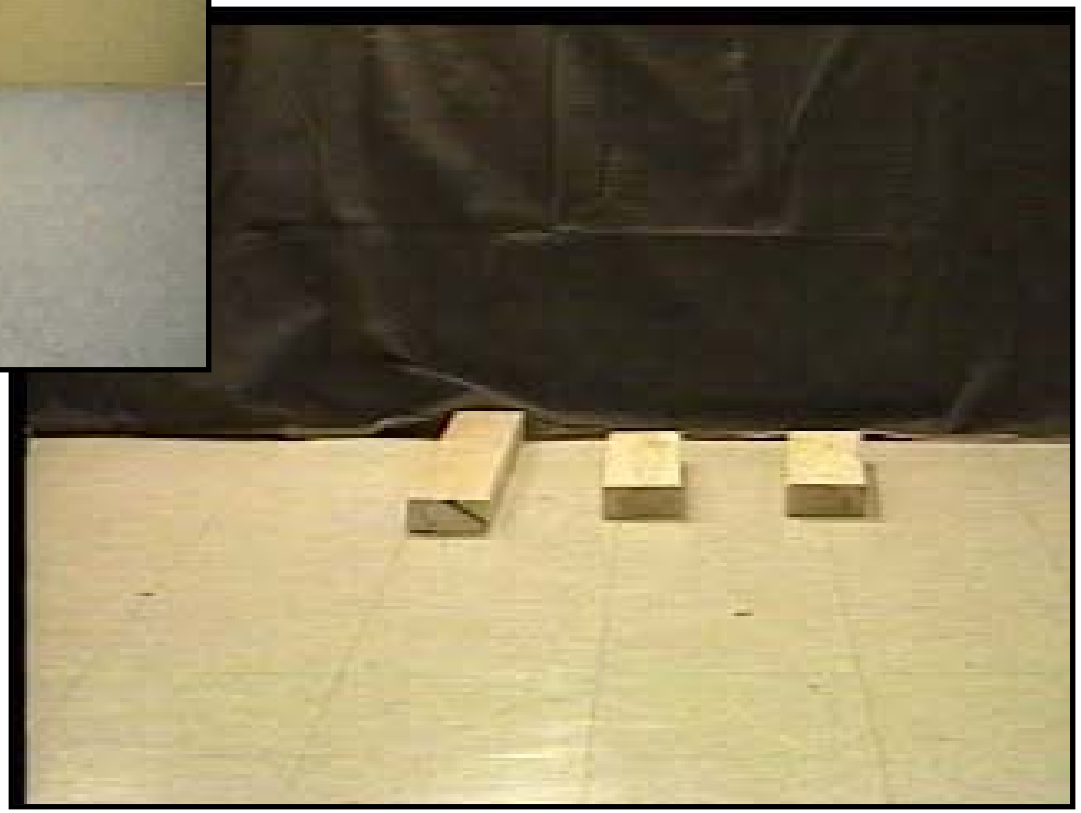
Snake Robots



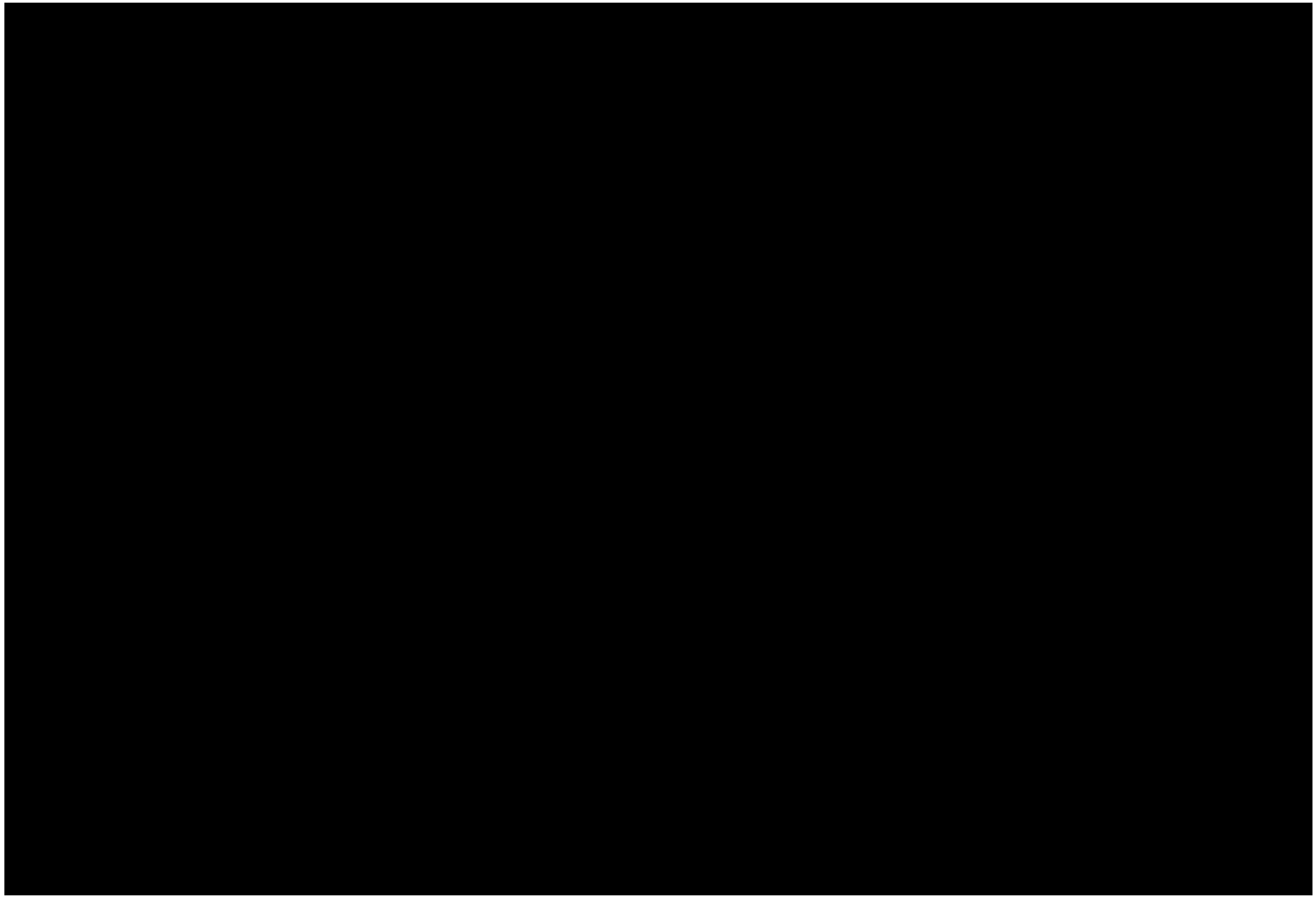
Carnegie Mellon Snakes

Carnegie Mellon Robots





Carnegie Mellon Pipe Robot



Dr. Gavin Miller’s Snake (S5)

Dr. Miller's Fifth Attempt

Current Status

- Draft report submitted 8/31/03
- Final version awaiting comments from draft review

Feasibility of In-Line Stress Measurement by Continuous Barkhausen Method

DOT Agreement No. DTRS56-02-T-0003

SwRI Project 14.06172

Status Review Meeting
October 7, 2003
Southwest Research Institute
San Antonio, TX

Project Description

- Relates to in-line inspection (ILI) for stress zones such as hard spots or mechanical damage
- Relates to magnetic flux leakage (MFL) inspection
- Contract signed 1 October 2002
- Project term 18 months (extended to 24 mo.)
- H. Rosen Engineering GmbH is co-funder and co-investigator.
- Total project cost is $ 160,000.

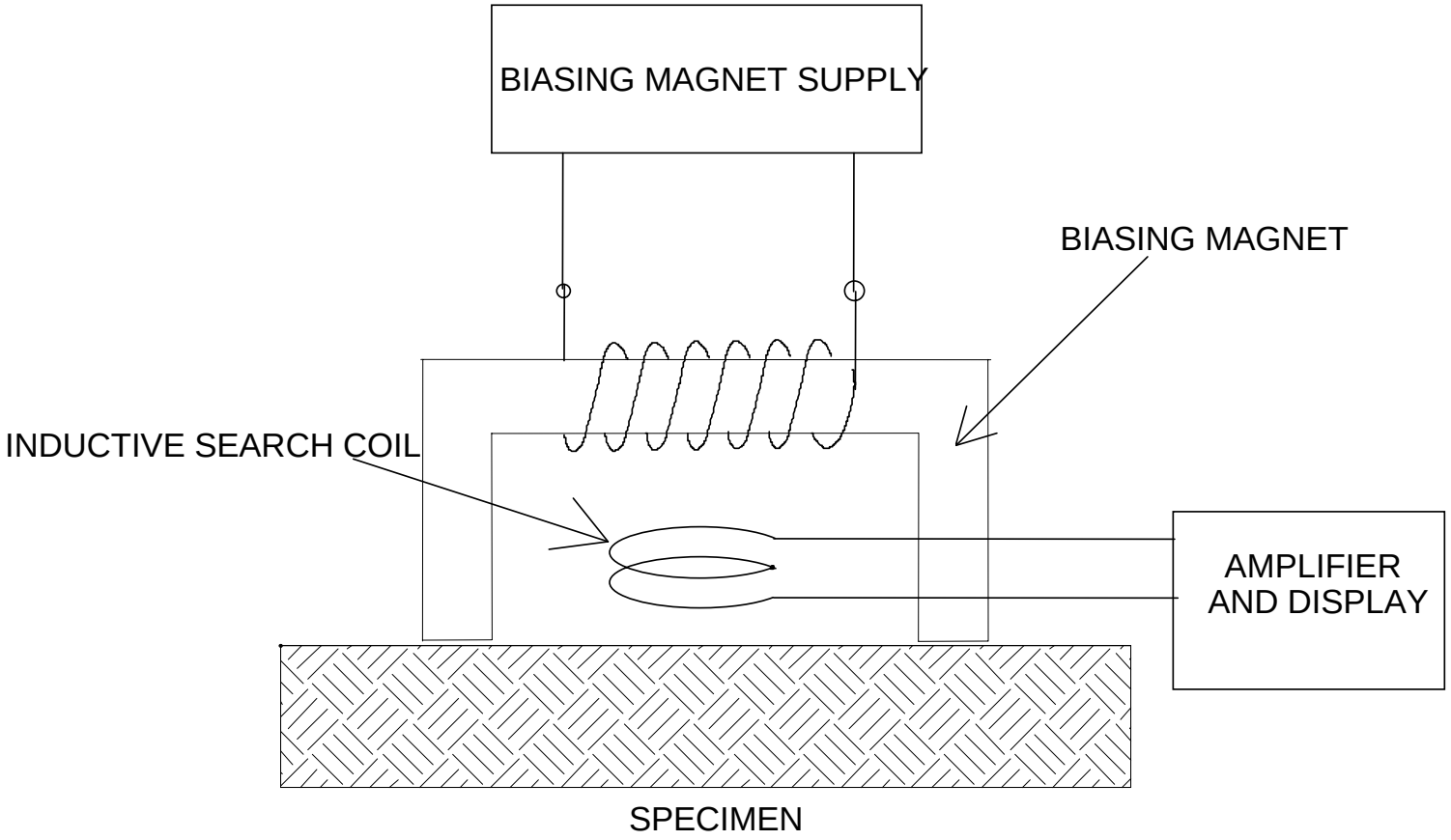
Project Goals

- Determine feasibility of implementing Continuous Barkhausen Noise (CBN) measurement on MFL smart pig.
- Determine optimum sensor design
- Determine optimum sensor location
- H. Rosen performs pull tests and field tests
- Produce comprehensive report of findings

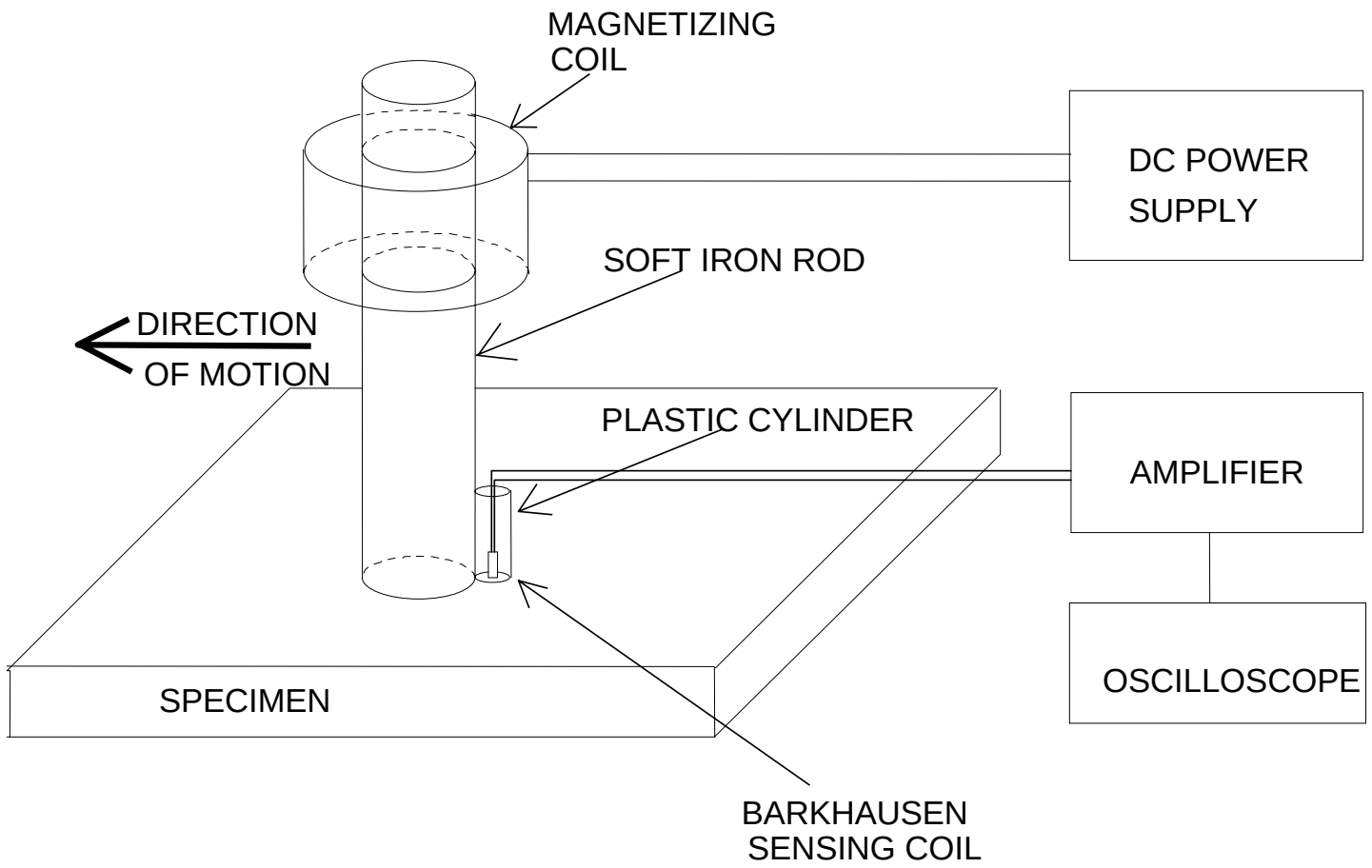
Properties of CBN System

- Takes advantage of earlier in-house work at SwRI
- Takes advantage of MFL pig magnetic field
- Simple sensor and circuitry
- Could expand capabilities of MFL ILI with minimal hardware addition
- Potentially more robust that competing ways of detecting stress anomalies

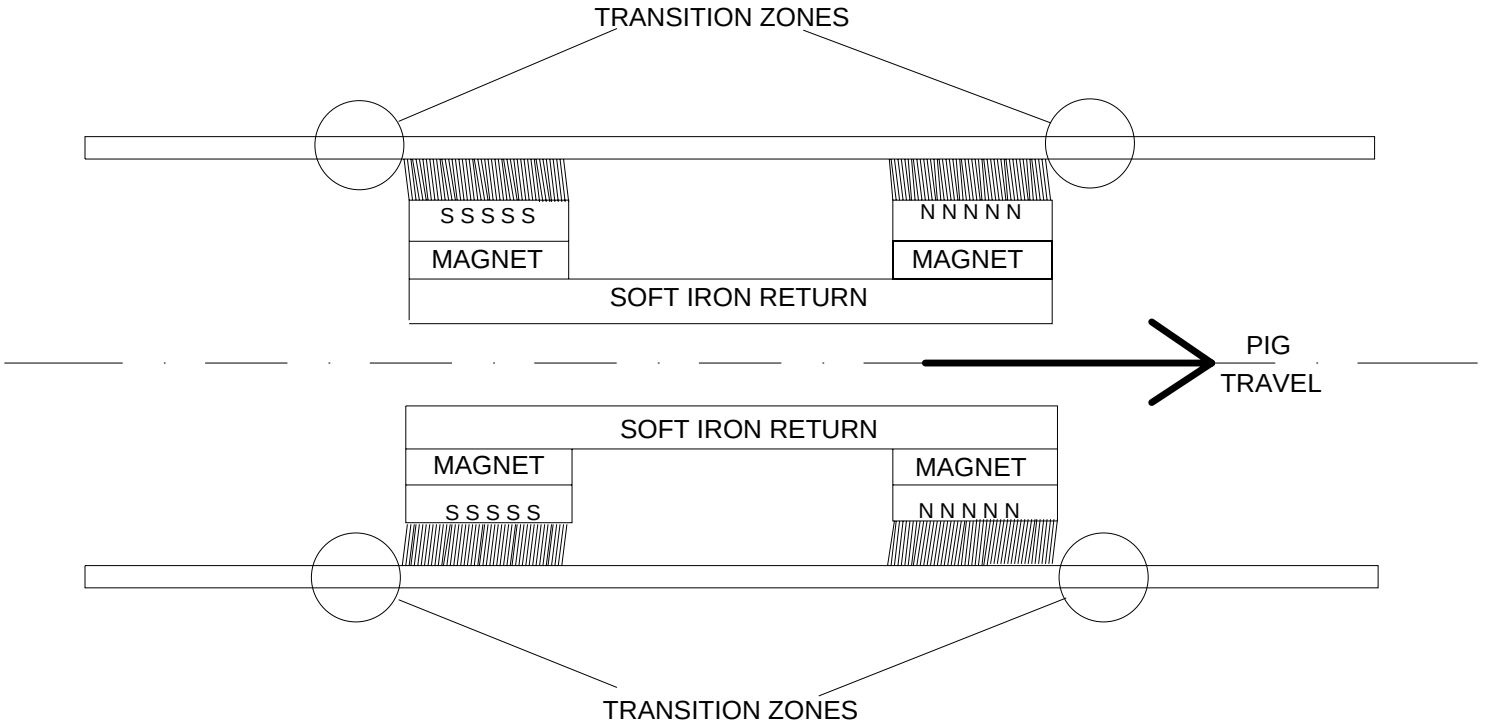
Conventional Barkhausen Circuit



Continuous Barkhausen Arrangement



MFL Pig Magnetic Circuit



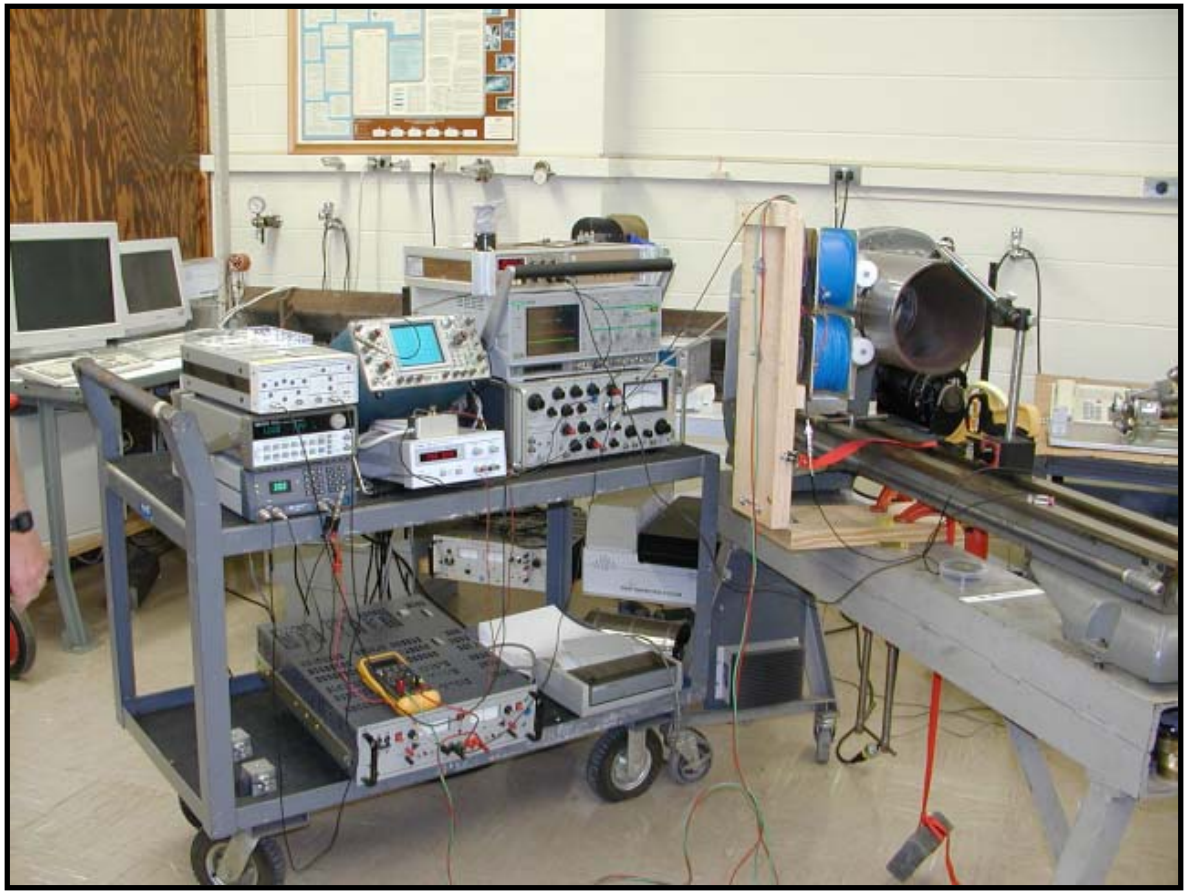
Current Status

- Rosen supplied magnetic field distributions around typical MFL pig
- Modeling was performed to suggest sensor placement
- Laboratory tests were performed to validate the technology
- Sensors and electronics were designed and fabricated to support pull testing.

Current Status (cont'd)

- Pull testing performed at Rosen facility in Houston validated effectiveness of sensor on MFL pig in detection of stress anomalies

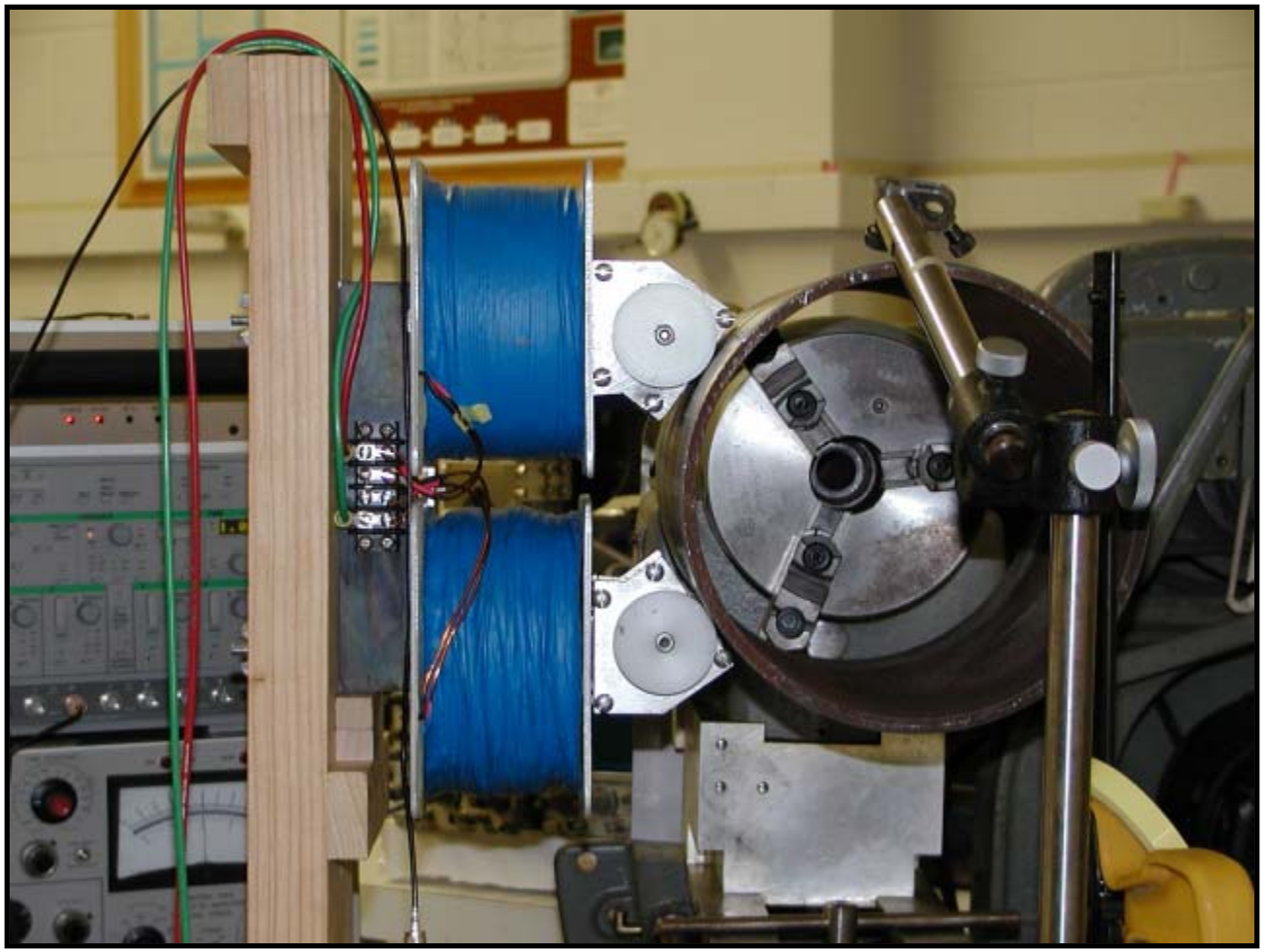
Laboratory Set-Up



Barkhausen Sensor

Peened Defect made with Pneumatic Scaler

Laboratory Continuous Barkhausen Apparatus

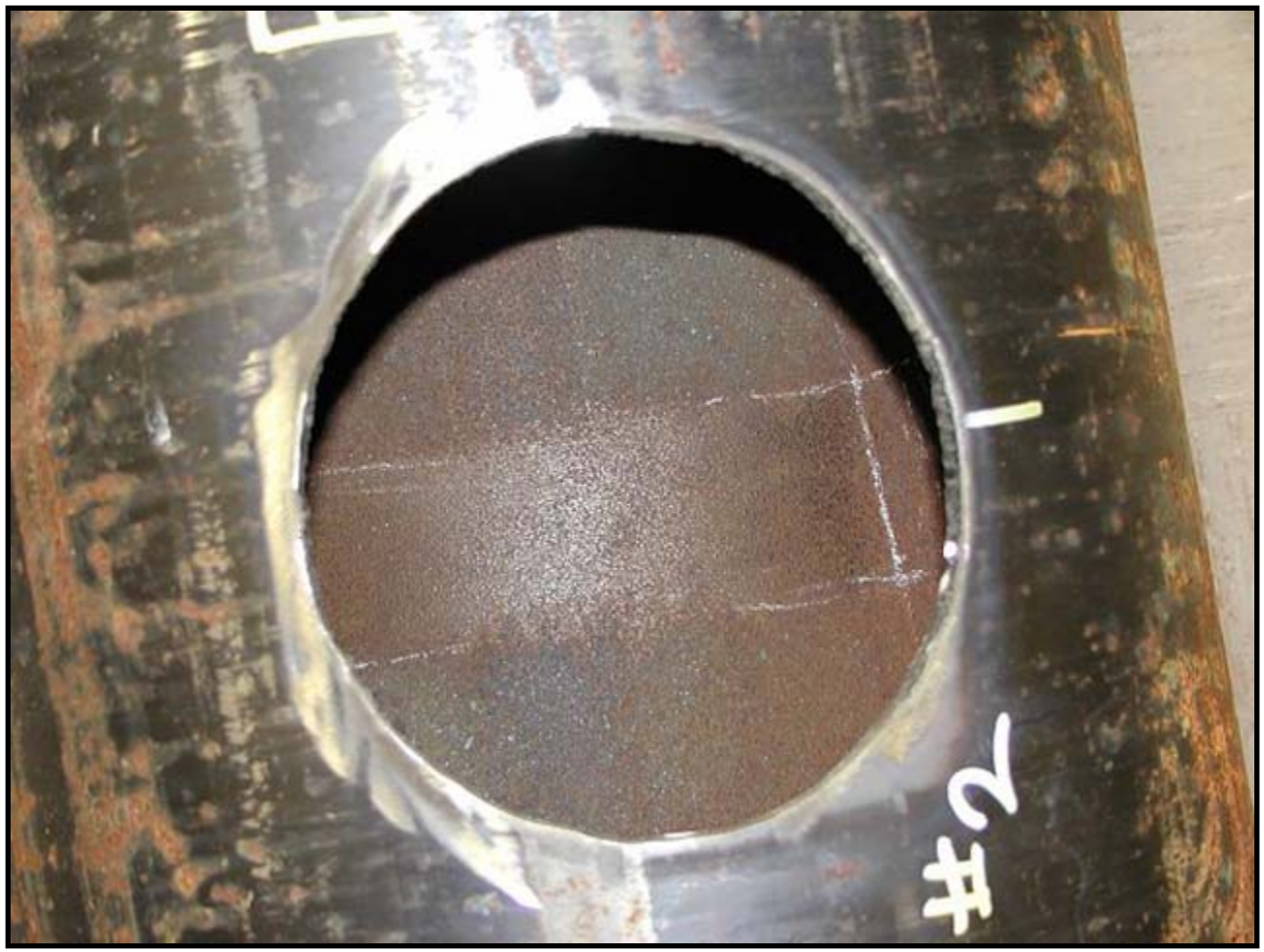


Pull Testing at Rosen

- Two specimens with multiple manufactured defects were provided by SwRI
- Specimens were assembled with other Rosen pipe to make 25m test section
- CBN sensors and electronics attached to Rosen MFL pig
- Multiple runs made at different speeds

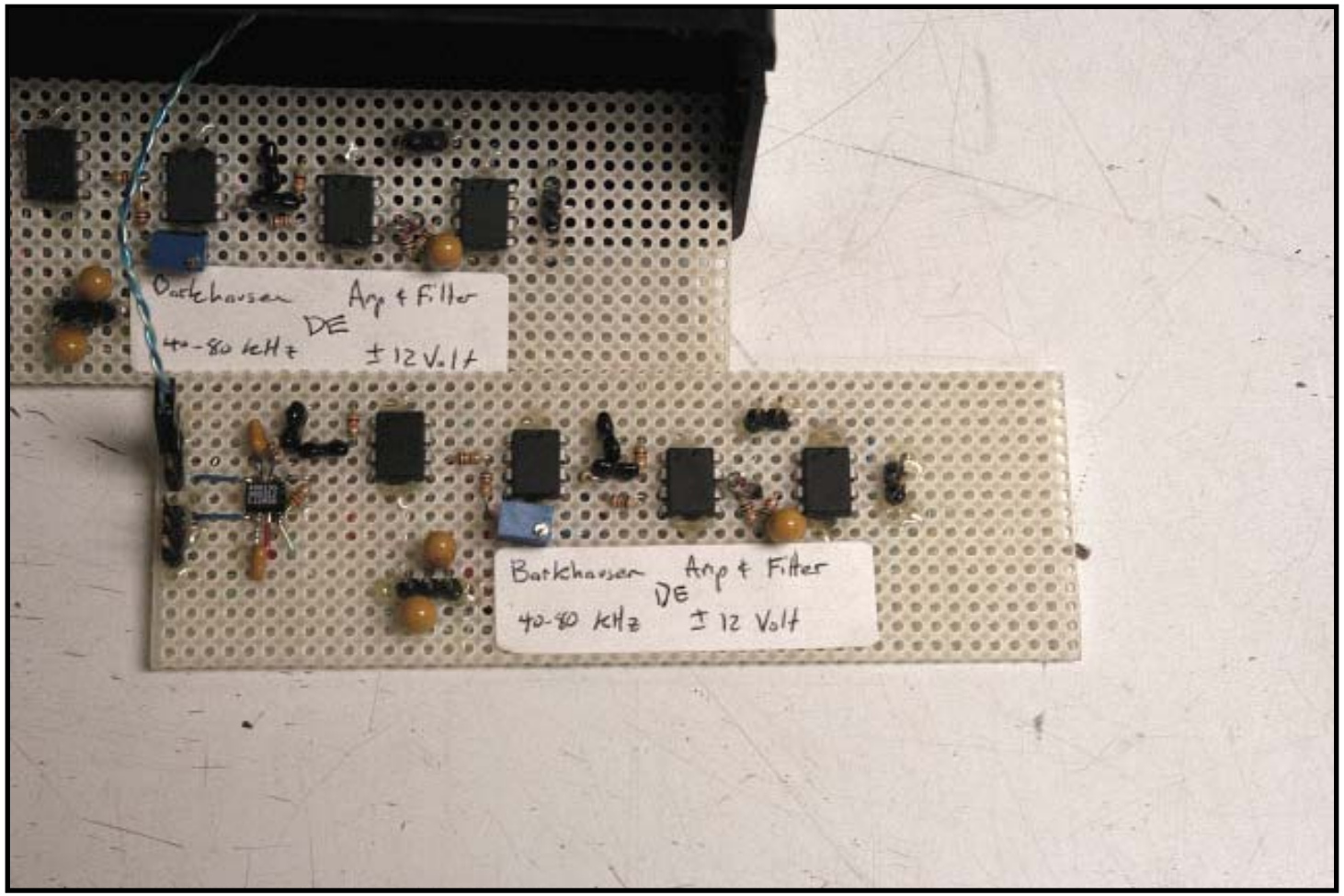
One Specimen for Pull Tests

Peened ID Defect



Quenched OD Defect

Interface Circuits



Barkhausen Pull-Test Line

17-Jul-03

Pipe measurement reference is at 12:00 (0 degrees) at the start end of the pipe, with angle CW in direction of travel.

Pipe No. 1: Diameter = 16 inches, Wall Thickness = 0.375" (9.5 mm) Inlet tray.

Axial Location Distance from launch (m)	Angular Position (Degrees)	Size	Item
0.00	N/A		Start of Pipe
1.52	0		End of launch tray
4.65	N/A		Pipe girth weld

Pipe No. 2: Diameter = 16 inches, Wall Thickness = 0.188" (4.8 mm)

Axial Location Distance from launch (m)	Angular Position (Degrees)	Size	Item
4.65	N/A		Pipe girth weld
6.49	0	1" dia.	Grind marks
6.49	0, 270		OD sensors
7.70	N/A		Pipe girth weld

Pipe No. 3: Diameter = 16 inches, WT = 0.375 inches (9.5 mm) Grade X-52 Welded

Axial Location Distance from launch (m)	Angular Position (Degrees)	Size	Item
7.70	N/A		Pipe girth weld
8.17	90	1" dia.	Drilled Hole
9.08	180	7" dia.	Hole with Coupon
9.08	0	2" ax. 10" circ.	Defect P1 - Peened Area on ID Surface
9.71	90	3" dia.	Defect P3 - Peened Area on OD Surface
10.30	180	7" dia.	Hole with Coupon
10.30	0	2" ax. 10" circ.	Defect Q1 - Quenched Area on ID Surface
10.37	0, 270	N/A	OD Sensors
11.52	180	7" dia.	Hole with Coupon
11.52	0	2" ax. 10" circ.	Defect P2 - Peened Area on ID Surface
12.15	90	3" dia.	Defect Q3 - Quenched Area on OD Surface
12.74	180	7" dia.	Hole with Coupon
12.74	0	2" ax. 10" circ.	Defect Q2 - Quenched Area on ID Surface
13.66	90	1" dia.	Drilled Hole
14.13	N/A		Pipe girth weld

Pipe No. 4: Diameter = 16 inches, WT = 0.188 inches (4.8 mm) Grade X-52 Welded

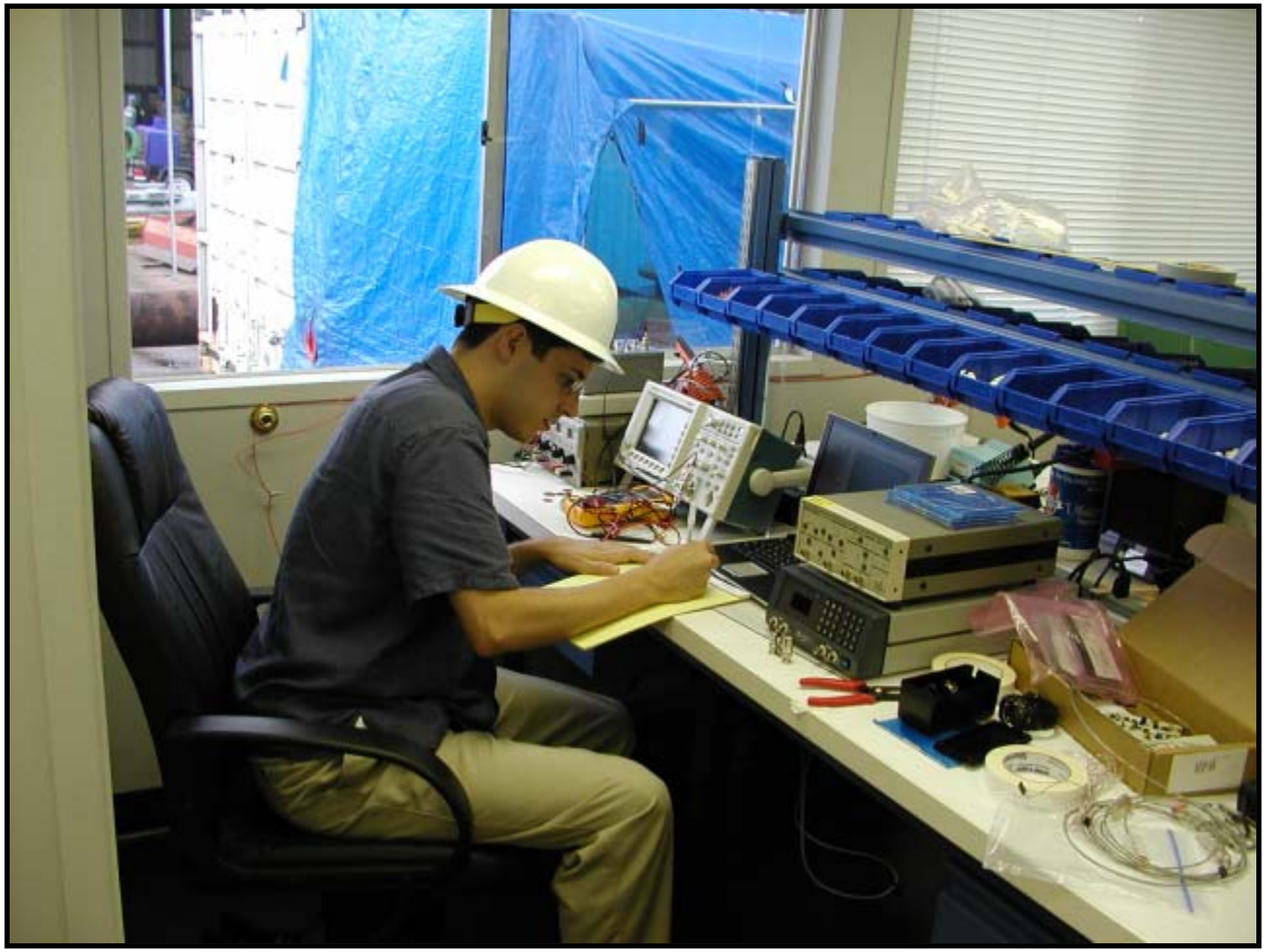
Axial Location Distance from launch (m)	Angular Position (Degrees)	Size	Item
14.13	N/A		Start of Pipe
14.45	180	1" dia.	Drilled Hole
15.36	180	7" dia.	Hole with Coupon
15.36	0	2" ax. 10" circ.	Defect P1 - Peened Area on ID Surface
15.96	90	3" dia.	Defect P3 - Peened Area on OD Surface
16.58	180	7" dia.	Hole with Coupon
16.58	0	2" ax. 10" circ.	Defect Q1 - Quenched Area on ID Surface
17.80	180	7" dia.	Hole with Coupon
17.80	0	2" ax. 10" circ.	Defect P2 - Peened Area on ID Surface
18.41	90	3" dia.	Defect Q3 - Quenched Area on OD Surface
19.01	180	7" dia.	Hole with Coupon
19.01	0	2" ax. 10" circ.	Defect Q2 - Quenched Area on ID Surface
19.91	0	2" ax. 10" circ.	ID Quench Defect - New
19.93	180	1" dia.	Drilled Hole
20.25	N/A		End of Pipe

Pipe No. 5: Diameter = 16 inches, Wall Thickness = 0.375" (9.5 mm). Receiver tray

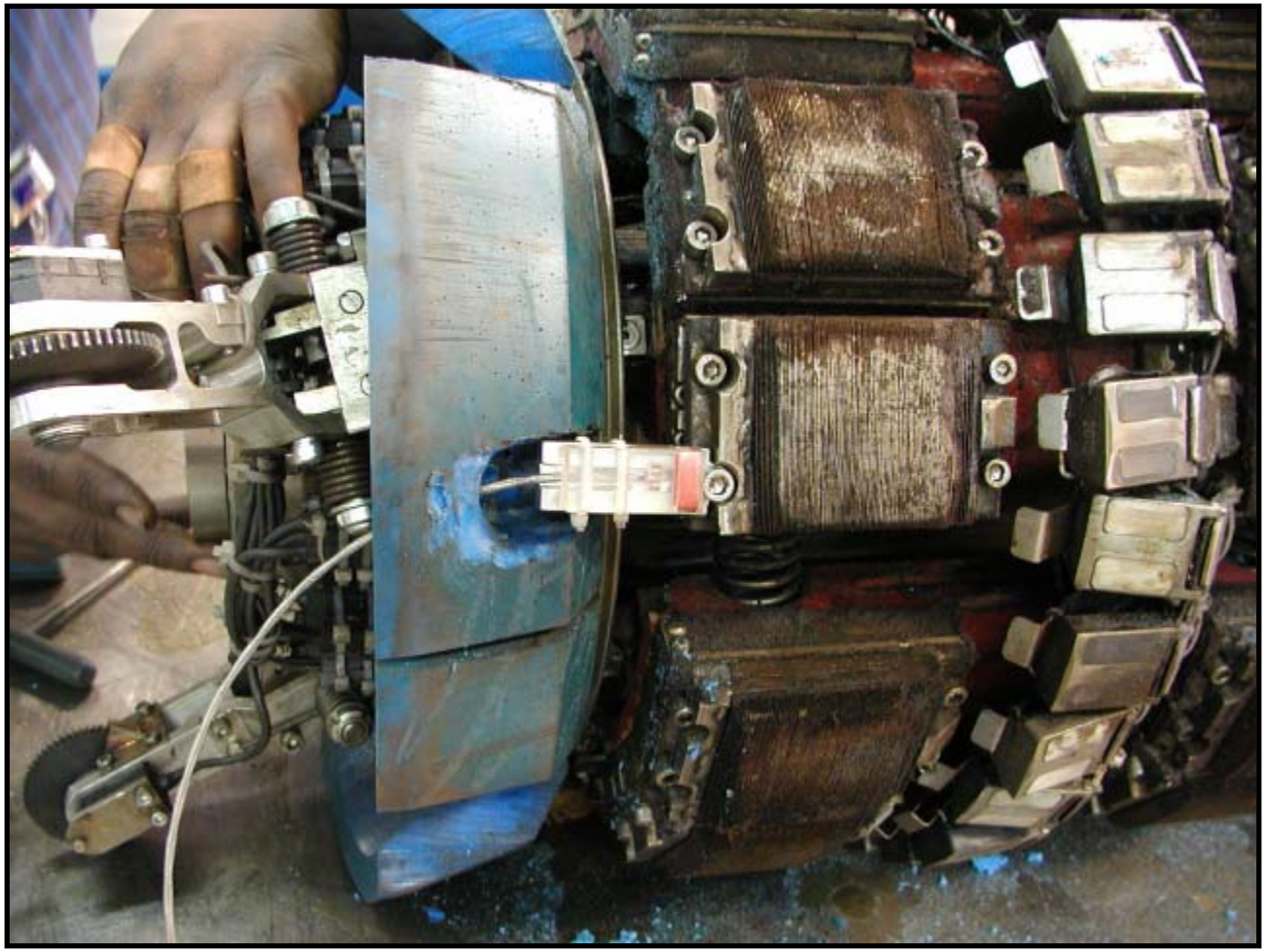
Axial Location Distance from launch (m)	Angular Position (Degrees)	Size	Item
20.25	N/A		Pipe girth weld
21.19	0	2" ax. 10" circ.	ID Quench defect - New
22.53	0	2" ax. 10" circ.	ID Quench defect - New
23.22	N/A		Receive tray
24.74	N/A		End of Pipe

Pull-Rig Set-Up
at Rosen Houston

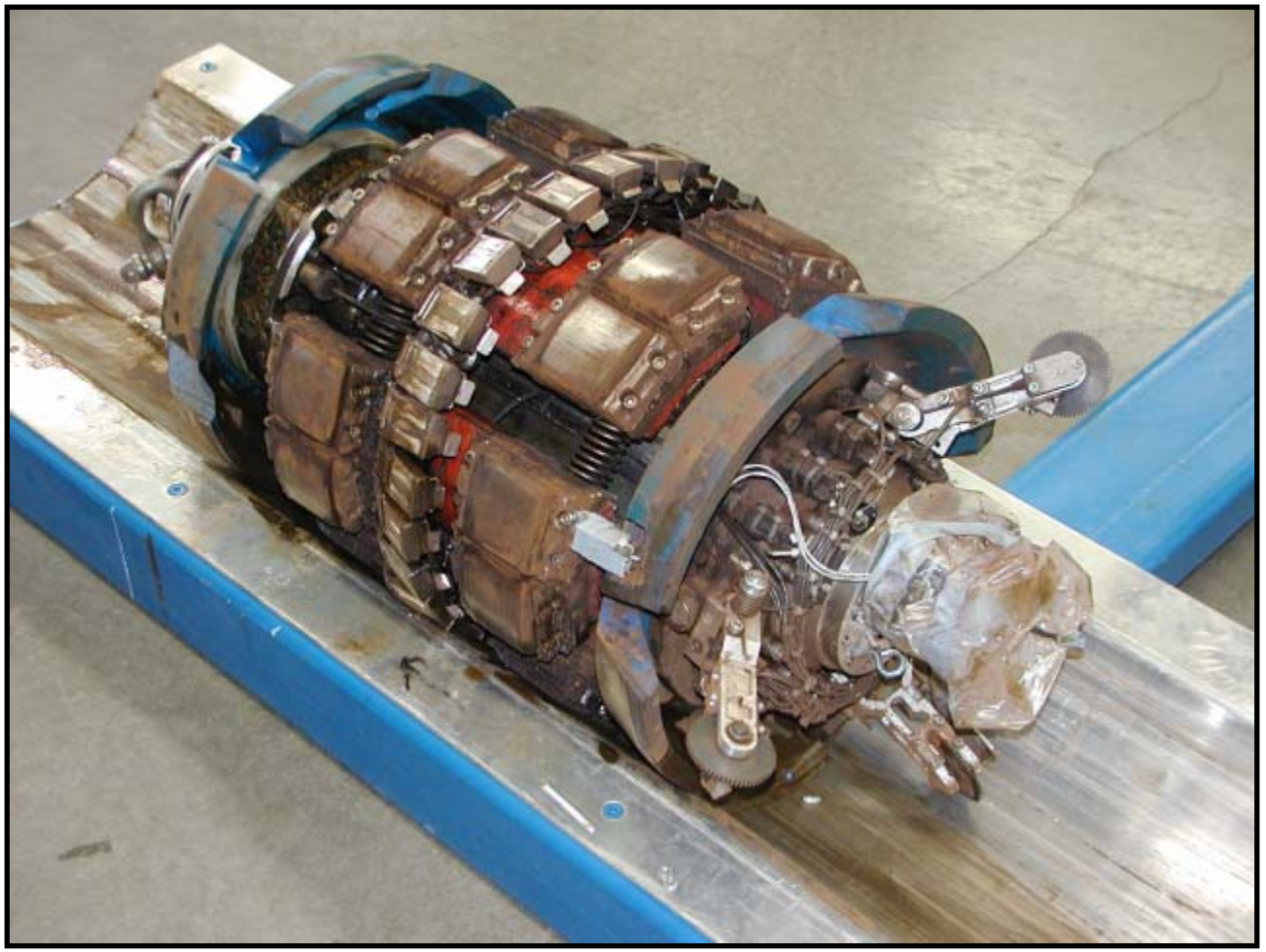
Data Acquisition and Storage



Barkhausen sensor attached to MFL pig magnetic pole piece

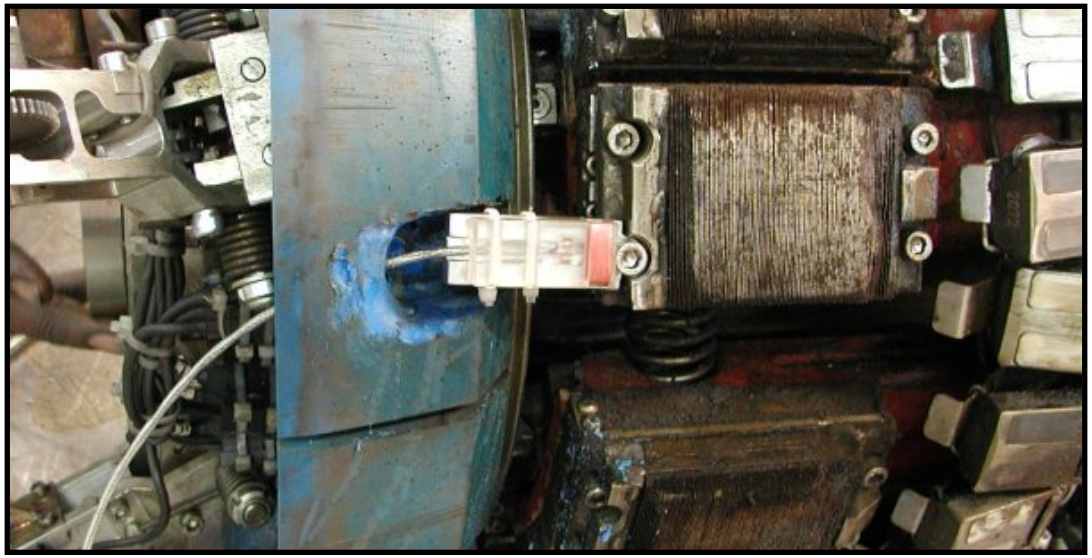


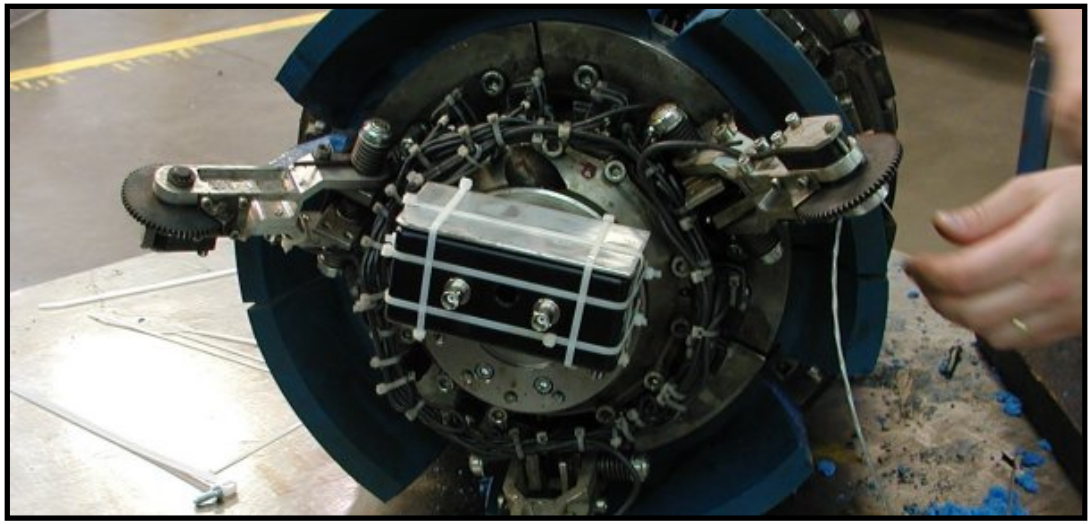
Rosen MFL pig in launch tray



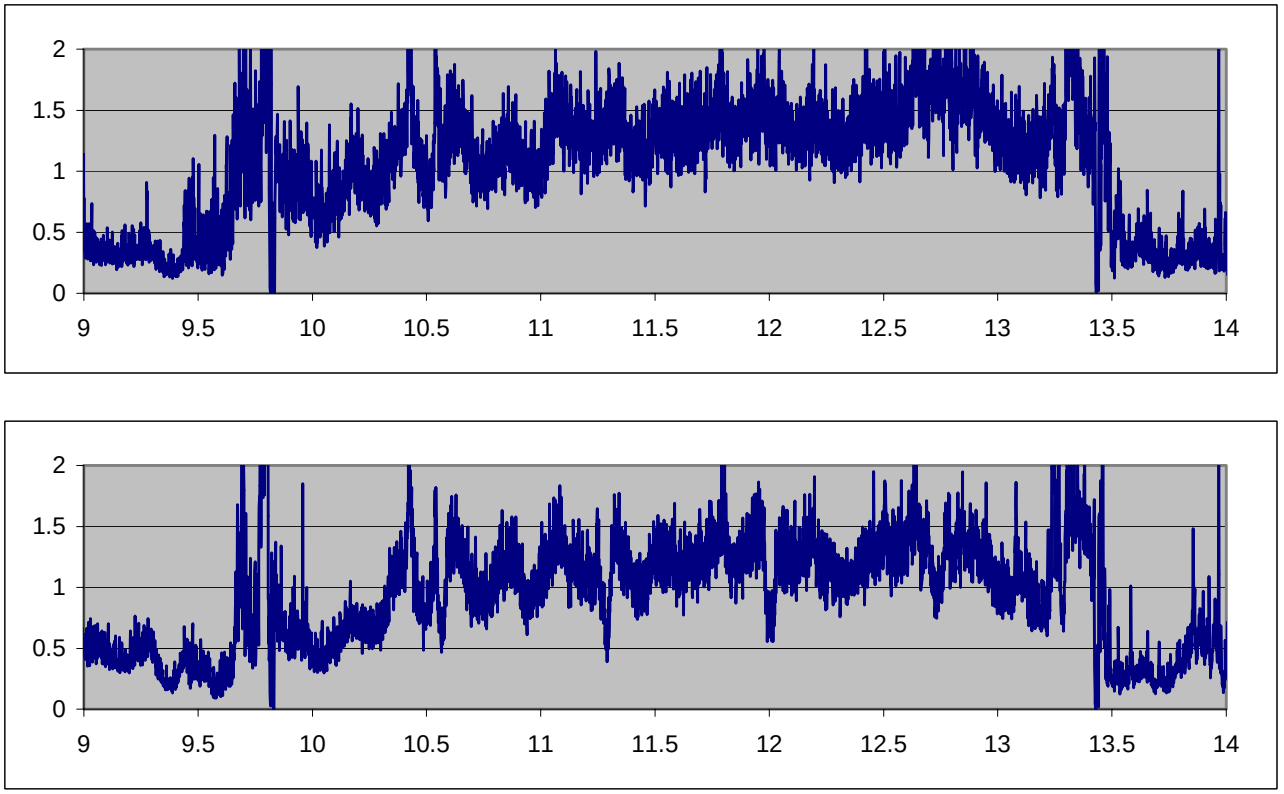
Pulling equipment and receiver tray

Sensor and interface circuit

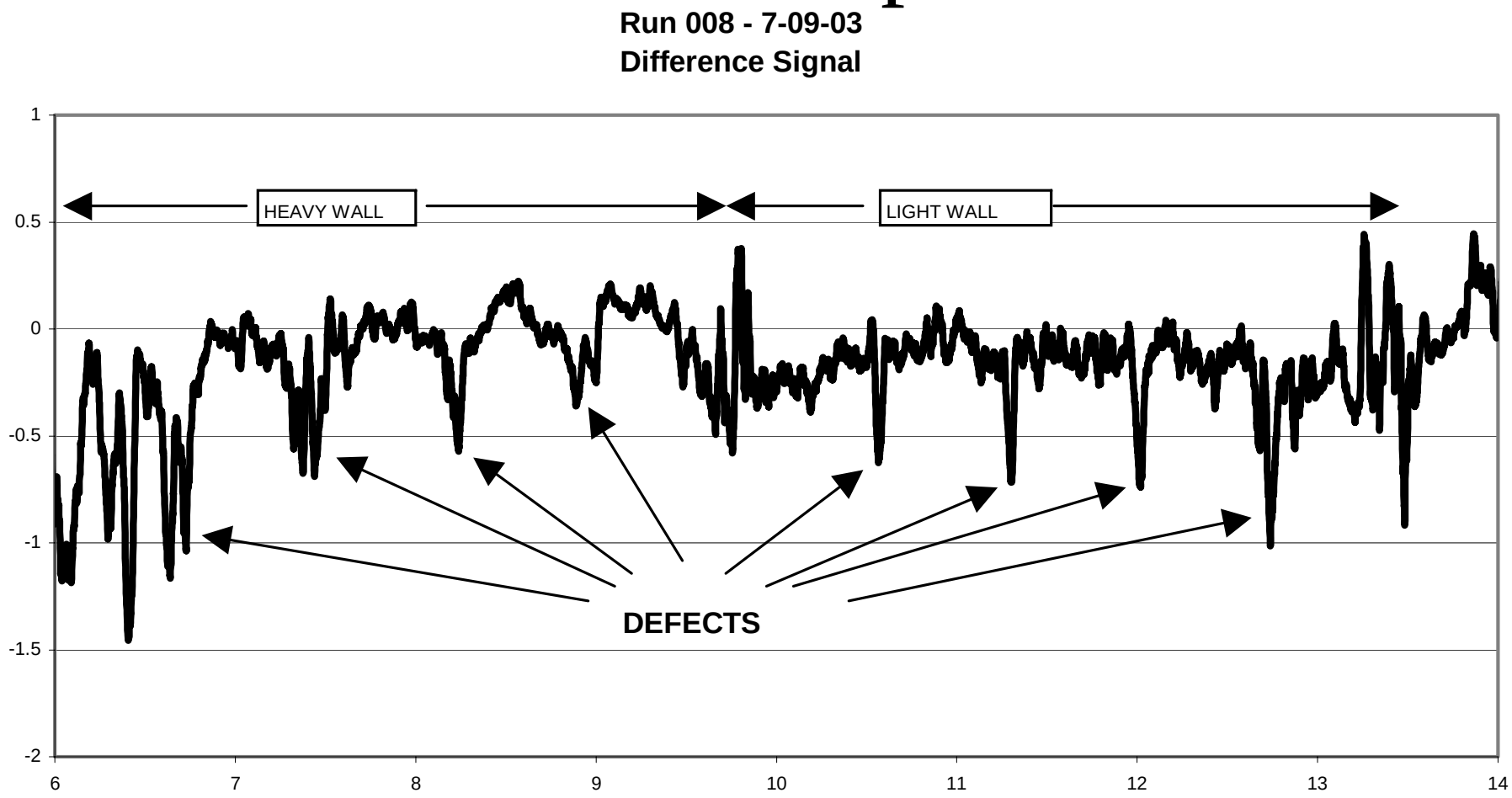




Raw Barkhausen signals from heavy wall and light wall pipes



Processed data from two test specimens



Status and Plans

- Analysis of data from pull tests continuing.
- Discussions are under way with Rosen on potential for field test